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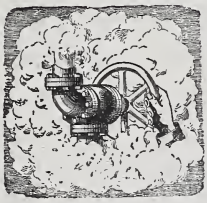

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INDEX TO VOLUME XVIII.

PAGE

Adams, A. D.: Electric Central Stations and Isolated Plants, . . 54

Air Chambers for Pumps, Suction, . . . F. M. Wheeler,. 516
Illustrated.

Aldrich, William S.: Electric Power for Factories, ... 194

Aluminium, The Widening Use of, ... 260

Aluminium for Foundry Patterns, ... 343

Aluminium Wire Electric Transmission Lines, ... 259

American Locomotives, The Increasing Size of, . Wm. Forsyth, . 146
Illustrated.

America's Position in the Industrial World, . . Walter M. McFarland, 10

Automobile Racing, ... 77
Illustrated.

Barstow, W. S.: Electricity in Large Cities, ... 373

Beard, George: Sixty Years in British Iron Works, ... 101
Illustrated.

Benjamin, Charles H.: The Development of Fly-Wheels, ... 248
Illustrated.

Beresford, Lord Charles: Openings for Mechanical Engineers in China, . . 290
Illustrated.

Biographical Sketches:

Cathcart, Wm. L., ... Admiral Geo. W. Melville, U. S. N., . 525

Isherwood, U. S. N., Commodore Benjamin F., . R. H. Thurston, . 344

Loring, U. S. N., Commodore Charles H., . . Walter M. McFarland, 262

Meier, Col. E. D., ... Robert W. Hunt, . 174

Pearson, Fred. Stark, ... W. P. Plummer, . 446

Blast Furnace Practice, A Curiosity in, ... 172
Illustrated.

Blowing-Off as a Boiler Scale Producer, ... 340

Boiler Explosion, Unusual Cause of, ... 342

Boiler Shop, The Modern, ... Joseph Horner, . 31
Illustrated.

Boilers in British Navy, Water-Tube, ... 520

Boilers with Too Much Heating Surface, ... 171

PAGE

Brass and Paint on Old-Time Locomotives 172
British Iron Works, Sixty Years in, . . . George Beard, . 101
Illustrated.
British Milling Machines, Some, ... Alfred Herbert, . 323
Illustrated.
Brough, Bennett H., Assoc. R. S. M.: The Oldest Association of Ironmasters, . 3
Illustrated.
"Building Balance" of the Middle-Age Cathedral Builders, The, . . . 443

Coal Consumption of Marine Auxiliary Machinery, ... 524
Carnegie, D.: Systematic Piece-Work Pricing, ... 74
Castings for Hydraulic Service, ... R. P. Cunningham, . 436
Cheap Power from the Coal Fields, ... 442
Chinese Trade Possibilities, ... 439
Chinese Workmen, Characteristics of 340
Civilising China, ... 439
Coal, The World's, ... Benjamin Taylor, F. R. G. S., . 393
Coal and Iron as Factors in Industrial Supremacy, ... 438
Compressed Air, A New Use for, ... 340
Compressed Air for Street Railway Traction, ... 258
Cunningham, R. P.: Castings for Hydraulic Service, ... 436

Dickie, George W.: Engineering Graduates from Universities, . . . 165
Dodge, W. C.: Invention as a Factor of American National Wealth, . . 198

ELECTRICITY:

Electric Cables for High Tensions, . . . Wm. Maver, Jr., . 467
Illustrated.
Electric Central Stations and Isolated Plants . . A. D. Adams, . 54
Electric Cranes in German Harbours, . . Louis J. Magee . 267
Illustrated.
Electric Power For Factories, ... William S. Aldrich, 194
Electric Motors, Gearing for, ... A. H. Gibbings, . 503
Illustrated.
Electric Riveting Machinery, ... F. Von Kodolitsch, 71
Illustrated.
Electricity as a Bye-Product 173
Electricity in Large Cities . . . . W. S. Barstow, . 373
Electrolytic Corrosion of Water and Gas Mains, ... 338
Engine and Boiler Weights per Horse-Power, ... 442
Engineering Graduates from Universities, . . George W. Dickie, . 165

Fitz Gerald, R. N., Rear-Admiral C. C. P.: The Imperial Japanese Navy, . 303
Illustrated.

Fly-Wheels, The Development of . . . . Charles H. Benjamin, 248
Illustrated.

PAGE

Forsyth, William: The Increasing Size of American Locomotives, . . . 146
Illustrated.

Foundry Cranes, ... Joseph Horner, . 214
Illustrated.

Gas Engine Fuels, Types, and Uses, . . . Prof. C. V. Kerr, . 425
Illustrated.

Gearing for Electric Motors, ... A. H. Gibbings. . 503
Illustrated.

Gibbings, A. H.: Gearing for Electric Motors, ... 503
Illustrated.

Gold Dredging Pay, How to Make, ... A. W. Robinson, . 480
Illustrated.

Gould, E. Sherman, M. Am. Soc. C. E.: Sugar Engineering in Cuba, . . 379
Illustrated.

Henderson, D. Sc., F. R. S. E., John: The Manufacture of Light, . . 336

Herbert, Alfred: Some British Milling Machines, ... 323
Illustrated.

Horner, Joseph: The Modern Boiler Shop, ... 31
Illustrated.

Foundry Cranes, ... 214
Illustrated.

The Paris Exhibition, ... 451
Illustrated.

Hot Water Heating from a Central Station, ... 173

Hull, George H.: Three Systems of Selling Pig Iron, ... 94

Hydraulic Power for Machine Tools, ... 77

Ice as an Insulator, ... 522

Installing a Propeller Shaft Without Docking, ... 444

Insulator, Ice as an, ... 522

Inventing, Practical, ... W. H. Smyth, . . 117
Illustrated.

Invention as a Factor of American National Wealth, . W. C. Dodge, . 198

Inventors, Women as 260

Iron, Making "Best Yorkshire," . . . Ewing Matheson,
Illustrated. M. Inst. C. E., . 179

Iron and Steel, The Increasing Demand for 259

Ironmasters, The Oldest Association of, . . Bennett H. Brough,
Illustrated. Assoc. R. S. M., . 3

Isherwood, U. S. N., Com. B. F.: The Sloop-of-War "Wampanoag," . 282, 403
Illustrated.

Japanese Navy, The Imperial, ... Rear-Admiral C. C. P.
Illustrated. Fitz Gerald, R. N., 303

Johnston, Arthur C.: American Ore Dock Machinery, ... 355
Illustrated.

Kerr, Prof. C. V.: Gas Engine Fuels, Types and Uses, ... 425
Illustrated.

		PAGE
Locomotive Weights, The Increase in,		445
Lodian, L.: Railway Notes from the Ural Range, Illustrated.		188
Machine Tools in Spain,		524
Machine Firing,		78
Machine Tools in the Mechanic Arts,	Dr. Coleman Sellers,	207
Machine Work, The Cost of,	Francis H. Richards,	170
Magee, Louis J.: Electric Cranes in German Harbours, Illustrated.		267
Magnalium,		521
Manufacture of Light, The	John Henderson, D. Sc., F. R. S. E.	336
Marine Auxiliary Machinery, Coal Consumption of,		524
Matheson, Ewing M., Inst. C. E.: Making "Best Yorkshire" Iron, Illustrated.		179
Maver, Jr., Wm.: Electric Cables for High Tensions Illustrated.		467
McFarland, Walter M.: America's Position in the Industrial World,		10
Biography of Commodore Charles H. Loring,		262
Mechanical Engineers in China, Openings for, Illustrated.	Lord Charles Beresford,	290
Meier, E. D.: The Power in a Pound of Coal,		65
Mels, Edgar: Trade Possibilities in South Africa, Illustrated.		83
Melville: Biographical Sketch of Wm. L. Cathcart,		525
Monopolies, The Growth of,		78
Monopolies Against Competition, The Struggle of,		79
Moving a Large Oil Tank, Novel Method of		443
Natural Gas Supply in the United States, The Diminishing, Illustrated.	George E. Walsh,	58
Naval Architecture and Sanitation,	J. R. Tryon, late Surgeon-General U. S. N.,	129
Noise and Wasted Energy,		522
Ore Dock Machinery, American, Illustrated.	Arthur C. Johnston,	355
Paris Exhibition, The, Illustrated.	Joseph Horner,	451
Piece-Work Pricing, Systematic,	D. Carnegie,	74
Pig-Iron, Three Systems of Selling,	George H. Hull,	94
Piston Valves for Locomotives,		342
Plummer, W. P.: Fred. Stark Pearson,		446
Portable Tool Rooms,		261

PAGE

PORTRAITS :

Akerman, Richard, ... 6
Cathcart, Professor Wm. Ledyard, ... 450
Isherwood, U. S. N., Commodore Benjamin F., ... 266
Kjellberg, J. C., ... 8
Loring, U. S. N., Commodore Charles H. 178
Meier, Col. E. D., ... 82
Pearson, Fred. Stark, ... 354
Tamm, Baron Gustav, ... 2

Power in a Pound of Coal, The, ... E. D. Meier, . . 65
Power from the Waves and Tides, ... 442
Pumps, Suction Air Chambers for, ... F. M. Wheeler, . 516
Illustrated.

Railway Accidents and War Losses, ... 441
Railway Notes from the Ural Range, ... L. Lodian, . . 188
Illustrated.
Reavell, J. A.: Water Cooling Towers, ... 510
Refrigerating Apparatus for Warship Magazines, ... 77
Refrigerating by Cold Brine Circulation from a Central Station, . . . 174
Richards, Francis H.: The Cost of Machine Work, ... 170
Riveting Machinery, Electric, ... F. Von Kodolitsch, 71
Illustrated.
Robinson, A. W.: How to Make Gold Dredging Pay, ... 480
Illustrated.

Sellers, Dr. Coleman : Machine Tools in the Mechanic Arts, ... 207
Selling Pig-Iron, Three Systems of, ... George H. Hull, . 94
Smith, Oberlin : Economies in Machine-Shop Work, ... 243
Smyth, W. H.: Practical Inventing, ... 117
Illustrated.
Spain, Machine Tools in, ... 524
Stanwood, J. B.: Recent American Steam Engine Practice, ... 488
Illustrated.
Steam Engine Practice, Recent American . . . J. B. Stanwood, . 488
Illustrated.
Steam Engines at the Paris Exhibition, ... 340
Steam Engines, Typical Horizontal British, . . W. D. Wansbrough, 15
Illustrated.
Steam Specialties, Economies from, ... 78
Steam Turbine Alternator, A 4000 H. P., ... 525
Strike Episode, A Curious, ... 341
Sugar Engineering in Cuba, ... E. Sherman Gould,
Illustrated. M. Am. Soc. C. E , 379
Taylor, Benj., F. R. G. S.: The World's Coal 393
Taylor-White Tool Steel Process, The 440
Thurston, R. H.: Biography of Benjamin F. Isherwood, ... 344

PAGE

Trade Possibilities in South Africa, . . . Edgar Mels, . 73
Illustrated.

Trades Union Coercion, A Workingman's Protest Against, ... 80

Transatlantic Service, Fast, ... 172

Tryon, J. R., late Surgeon-General U. S. N.: Naval Architecture and Sanitation, 129

United States Railroad Statistics for 1899, ... 445

"Variag," The Russian Cruiser, ... 440
Illustrated.

Von Kodolitsch, F.: Electric Riveting Machinery, ... 74
Illustrated.

Walsh, George E.: The Diminishing Natural Gas Supply in the United States, . 58
Illustrated.

"Wampanoag," The Sloop-of-War, . . . Com. B. F. Isherwood,
Illustrated. U. S. Navy, 282, 403

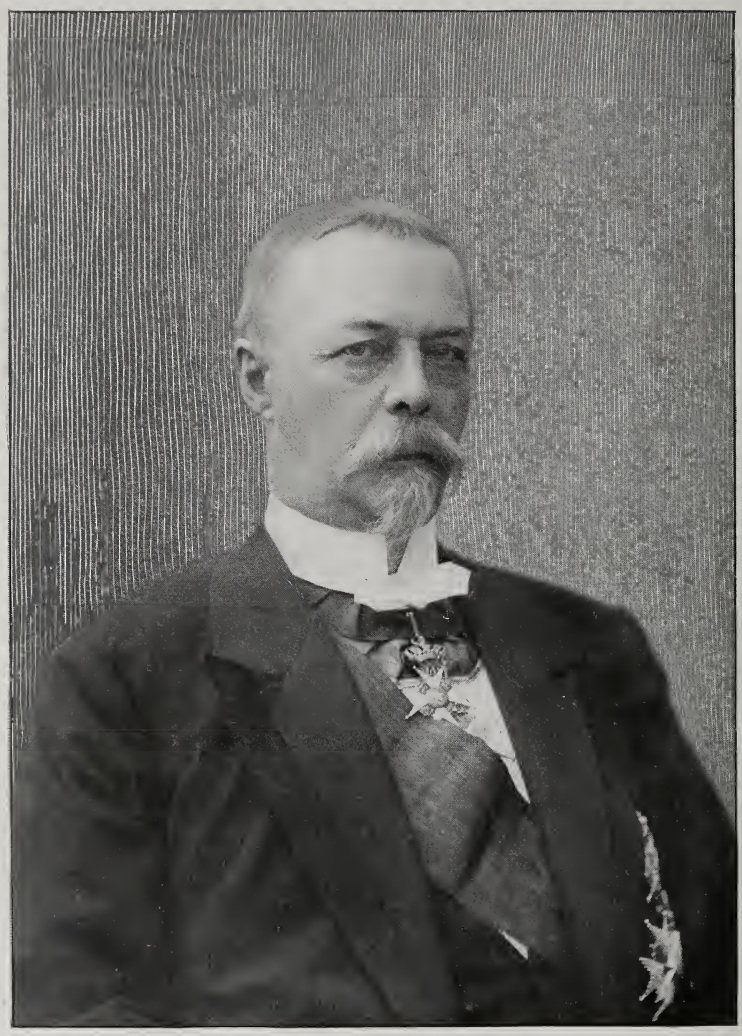
Wansbrough, W. D.: Typical Horizontal British Steam Engines, . . . 15
Illustrated.

Waste of Fuel from Boiler Scale, The, ... 339

Water Cooling Towers, ... J. A. Reavell, . . 510
Illustrated.

Water-Tube Boilers in the British Navy, ... 520

Wheeler, F. M.: Suction Air Chambers for Pumps, ... 516
Illustrated.



BARON GUSTAV TAMM

GOVERNOR OF STOCKHOLM AND PRESIDENT OF THE SWEDISH IRON AND STEEL INSTITUTE

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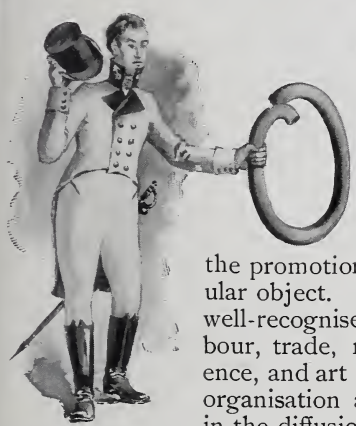
CASSIER'S MAGAZINE

VOL. XVIII MAY, 1900 No. 1

THE OLDEST ASSOCIATION OF IRONMASTERS

By Bennett H. Brough, Assoc. R. S. M.



THE OFFICIAL UNIFORM OF SWEDISH IRONMASTERS

OF late years there has been a very general tendency among individuals to form associations for the promotion of some particular object. In almost every well-recognised branch of labour, trade, manufacture, science, and art there exists some organisation actively engaged in the diffusion of knowledge, and some of these societies have attained a respectable antiquity. The British Society of Arts, for example, which was the first to deal with technical matters, was founded in 1753 and still continues its career of usefulness with undiminished vigour; the Institution of Civil Engineers of Great Britain, a vast organisation which grows in numbers and importance every year, was founded in 1818. The desire for a free exchange of ideas has led to a rapid growth of similar societies, and much of the progress in mining and metallurgy is directly traceable to them.

Of societies dealing with metallurgy, the first established in Great Britain was the Iron and Steel Institute. This owed its origin, in 1869, to an opinion very generally entertained by the British iron manufacturers that great advantages might be anticipated from an organisation based on the same general principles as the many existing societies founded for the promotion of scientific inquiry and of practical improvements in other important spheres of industry. Soon after the inauguration of the Institute, it became apparent that there was a desire among the members to add unreservedly to the general stock of information. The willingness to be enrolled in its ranks was not confined to British ironmasters, but extended itself to Continental and American metallurgists, and after the first Continental meeting, held at Liège in 1873, the Institute acquired the cosmopolitan character that it has since retained. To the papers read at its meetings and the discussions that followed them Mr. John Fritz, the veteran American metallurgical engineer, has ascribed much of the American success in metallurgy. Certainly, as Dr. James Douglas pointed out in a recent presidential address to the American Institute of Mining Engineers, no special literary organ of any art contains such frank discussion of processes and methods as the Journal of the Iron and Steel Institute. It may be inferred, therefore, with justice, that the candour with which ironmasters discuss their trials and tribulations and the progress achieved in iron and steel making are intimately related as cause and effect.

In the United States, the American

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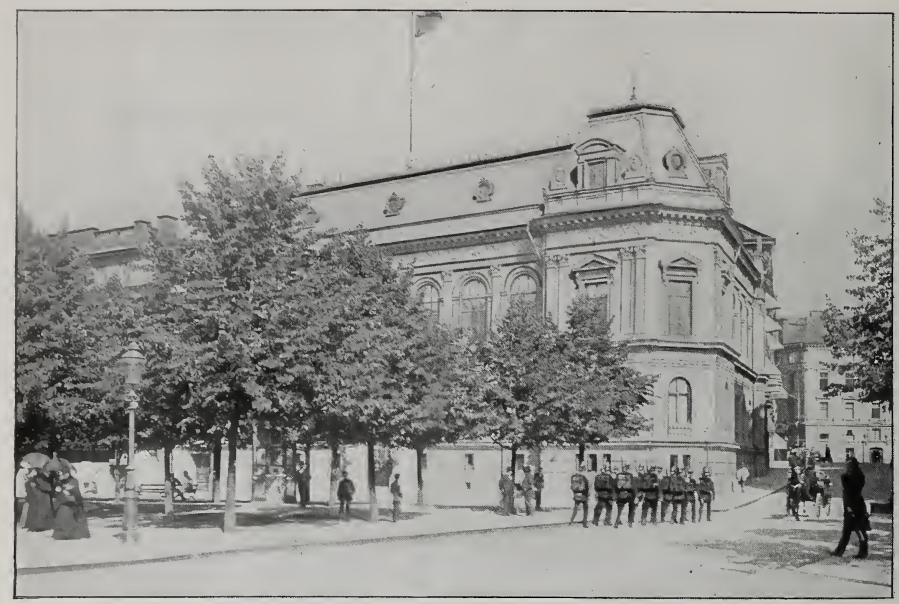


THE HOME OF THE SWEDISH IRON AND STEEL INSTITUTE

Institute of Mining Engineers was founded shortly after, and from its start, in May, 1871, up to the present time, it has had a career of uninterrupted prosperity, and has published a large number of papers of permanent value on all branches of mining and metallurgy. In Great Britain, the Institution of Mining Engineers, which is a federation of six local mining societies, was not founded until later. Independent action is left to each society, but all the papers read are published in one Journal, the first volume of which was issued in 1889.

It is curious to note that exactly a hundred years before that date the first volume of the transactions of an international society with similar aims was published. This society was founded by Ignatius von Born in Hungary, and included members from fifteen different countries. Among the members were James Watt, the inventor of the modern steam engine; Matthew Boulton, his partner; Sir William Hamilton; Goethe, the poet; Lavoisier, the illustrious French chemist; Sven Rinman, the great Swedish ironmaster; and many of the most brilliant investigators of the period. Owing to the death of the founder, the society came to an end in 1791. Its finances were in a critical condition; its leading French members perished on the scaffold during the Reign of Terror; and its other losses by death were very great. But it did excellent work during its brief existence, and the ideas embodied in its constitution were destined to be developed in a remarkable manner.

This society was, however, not the oldest metallurgical organisation, for, early in the eighteenth century, in Sweden, the classic home of metallurgy, an association of ironmasters was founded by Anders Bachmansson, a prominent ironmaster, who was subsequently ennobled for the services rendered by him to the iron industry of his country. A petition, addressed by him to the privy council, caused a royal commission to be appointed to consider the formation of an iron institute. The result of this was the decision that such an institute, or *Jernkontoret*, as it was called, should be established at Stockholm to regulate the iron trade. Operations were begun in 1748. The primary object of the founder was to

render financial assistance to ironmasters during critical times.

Such histories as that of the Stora Kopparberg Company, the oldest joint stock company in the world, the foundation of its business going back to the first half of the thirteenth century, show the wealth and power of Swedish iron works during the Middle Ages; but these prosperous years were followed by periods of depression, and some time before the foundation of the iron institute mentioned, many ironmasters were in the power of their customers, who used their advantage to depress the price of Swedish iron.

From 1720 to 1740 the iron industry of Sweden was of great importance. The production of iron was twice as great as that of Great Britain. Even at an earlier date, in the time of Charles II., British manufacturers were obliged to petition the king to forbid the importation of Swedish iron in order that the British iron trade might be permitted to subsist.

When the Institute was founded, the government granted it a loan in order to enable it to begin its work. Funds were also raised by fees from the members, whose contribution was a copper "daler" for every "skålpund" of bar iron made. The basis of the loan system was that ironmasters should be allowed to mortgage iron in the State Bank and that the Institute should refund the interest of 4 per cent. The Institute was also empowered to buy up iron when necessary. The same principles of raising subscriptions have continued ever since, and the available funds have constantly increased. The original rules were signed by the king on December 29, 1747, and the rules now in force were sanctioned by King Oscar on January 26, 1894. This admirably conducted Institute has another sphere of usefulness for which it deserves the thanks of all countries, and that is, the promotion of metallurgical knowledge and the advancement of technical education. These objects have been attained in a remarkable degree, partly by maintaining eminent experts and teachers, partly by annual grants to mining schools, partly by contributions

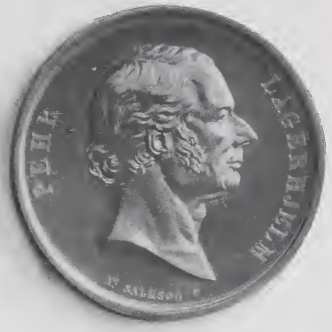
THE RECEPTION ROOM IN THE JERNKONTOR BUILDING

PROFESSOR RICHARD ÅKERMAN, DIRECTOR-GENERAL OF THE SWEDISH BOARD OF TRADE

in aid of metallurgical research, and partly by disseminating throughout the kingdom, by means of its journal, reports of the scientific and technical progress made throughout the world. The journal, *Jernkontorets Annaler*, is one of the oldest technical periodicals in existence, having been started as early as 1817.

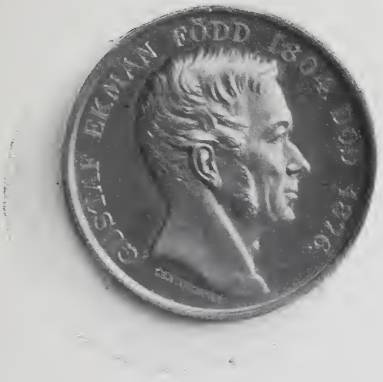
The gold medal awarded by the Institute to those who have been conspicuously successful in promoting the Swedish iron industry is a coveted distinction. Among the recipients of this medal still living are the veteran ironmaster, G. F. Göransson, of Sandviken, who, in 1858, was the first to make the Bessemer process a success in Sweden, and General O. M. Björnstjerna, who, when Swedish Minister in Russia, rendered valuable services to the iron trade. In 1894 it was awarded to Prof. Richard Åkerman, Director-General of the Swedish Board of Trade, the greatest living Swedish metallurgist, who had previously, in 1885, received the Bessemer Gold Medal of the British Iron and Steel Institute. In 1897 it was awarded to Mr. F. Richter, who for so many years has ably filled the office of secretary, and in 1898 to Professor G. Nordenström, who has done more than any one else in elucidating the complex nature of Swedish mineral deposits.

Since 1822 the Iron Institute has possessed the unusual privilege of awarding a silver medal for technical industry and skill, to be worn on the left breast. A similar medal in gold may be awarded for extraordinary services. This highest honour has been conferred on three occasions, namely, on Scheele, in 1832; on Morell, in 1844; and on Gustav Ekman, in 1868. Another curious privilege possessed by the Institute is that its officers may wear a special uniform, authorised by Royal decree of October 16, 1817.



MEDAL AWARDED TO PEHR LAGERHJELM, 1856

Looking back on the history of the metallurgy of iron in Sweden, we see that all the notable inventions and researches during the past one hundred and fifty years have been carried out under the auspices of the Institute. In 1751 it was decided to appoint a practical and scientific man to carry out b'ast



MEDAL STRUCK IN HONOUR OF GUSTAF EKMAN IN 1877

THE REVERSE OF THE EKMAN MEDAL

THE MEETING ROOM

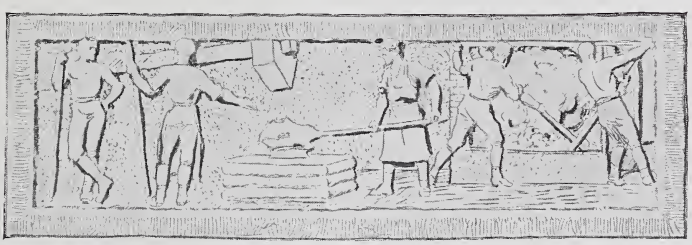
furnace investigations, and Sven Rinman (1720-1792), who, in his monumental treatise, published in 1782, was the first to combine theory with practice in the metallurgy of iron, was appointed head furnace master (Öfvermasmästare). Considerable financial support was also given him in the publication of his works. The publication of numerous other technical works, such as Garney's treatise on the construction of blast furnaces, is also due to the liberality of the Jernkontor. Among other eminent names closely associated with the Jernkontor mention must be made of the great metallurgical chemists, Brandt and Torbern Bergman; Gustav Ekman, who invented the gas reheating-furnace, which rendered possible the remarkable development in Sweden of the Lancashire hearth firing process; Westman, whose gas kiln, perfected in 1851, has since been in general use in Sweden; C. A. Casperson, whose ingenious converter-ladle is used at most Swedish Bessemer works; C. Wittenström, who has succeeded in obtaining sound steel castings by the addition of aluminium; I. A. Brinell, who has ably investigated the heat treatment of steel; V. Eggertz, the founder of the modern methods of assaying; Pehr Lagerhjelm and Knut Styffe, who so greatly advanced the methods of mechanically testing iron and steel; E. J. Ljungberg, who, at Domnarfvet, has shown the advantages

J. C. KJELLBERG, PAST TREASURER OF THE SWEDISH IRON AND STEEL INSTITUTE

of manufacturing iron and steel on a large scale; and lastly, J. C. Kjellberg, who adds to his skill as an ironmaster, acquired at Bofors, that conspicuous financial ability shown by him during his tenure of office as treasurer of the Institute's funds.

The management is vested in a board, composed of five ordinary and five extraordinary members, elected by the Society of Ironmasters. The former consist of the president, Baron Gustav Tamm, the Governor of Stockholm; Count Cronstedt, Lord-in-Waiting; Colonel Geiger, Mr. G. F. Berndes and Mr. M. S. Nisser. The extraordinary members take part in the proceedings only when invited to do so by the others. The fine building owned by the Jernkontor is situated in the best part of Stockholm. It was begun in 1873 and finished in 1875. The most striking feature of the exterior is Kjellberg's frieze, a work of great artistic merit, representing the development of the manufacture of iron. There are also medallion portraits of Scheele, Berzelius, Bergman and other famous Swedish metallurgists. The interior of the building had an unwonted appearance on the occasion of the reception given to the members of the British Iron & Steel Institute during their visit to Stockholm, when a profusion of shrubs and flowers, a large bust of King Oscar, British and Swedish flags, bright draperies, and rich furniture helped to decorate the lofty rooms and staircase. The brilliancy of this festivity was an indication of the lavish hospitality with which the visitors were received at one of the pleasantest meetings ever held by the British Iron and Steel Institute.

For more than one hundred and fifty years the Jernkontor has steadily carried on its useful work in furthering the metallurgy of iron. Founded in a truly patriotic spirit, it continues to exercise a widespread influence, and, with the hearty co-operation of the Swedish ironmasters, it well obeys the precept, "*Hortor amare focos*," that may be read on the medal struck to commemorate its foundation.



PORTION OF FRIEZE OF THE JERNKONTOR BUILDING

AMERICA'S POSITION IN THE INDUSTRIAL WORLD

By Walter M. McFarland

THERE has been a great deal of discussion recently in both the technical and general press of America's position in the industrial world, or, as it is often put, "American competition with the industrial nations of Europe," and there seems to be a feeling of astonishment that America could possibly compete with the long-established concerns of the European countries, particularly Great Britain. Why, however, there should be any astonishment that a time should come when America would be a keen competitor is really hard to see, for that country possesses to an unusual degree all the elements necessary to great success, and the surprise should be not that the competition has at last become so keen as to make the older countries feel that their supremacy is slipping away, but rather that the struggle did not come sooner. Possibly there is some justification for the non-American, however, because of the fact that for so many years nearly all American manufacturers insisted on the importance of protective duties, claiming that, if exposed to free competition with the manufacturers of Europe, they would be unable to continue in business.

The main reason, doubtless, for America's failure to appear earlier as a competitor for business outside her own borders is that for many years immigration was so great that a market was provided right at home which was capable of absorbing more than the home output. There were years when the immigration amounted to as much as 700,000 people,—a population about seven times that of the entire Hawaiian group and about half as great as that of some of the South American countries. A commercial treaty which gives a manufacturing country special advantages with some other country having a population of a few millions is considered a remarkable feat of diplomacy, and yet a much better market was provided for America every few years without any effort at all.

In the course of time the annual immigration and natural increase formed a much smaller percentage relative to the previous population, while the manufacturing industries had been rapidly multiplied, and the inevitable consequence was that the output was greater than the home consumption instead of less, with the result that new markets were sought. This may explain, to some extent, why America has become a competitor for the world's business; but it still remains to show why she should be able to surpass in some lines the work of the older countries where these same lines have been conducted for a much longer period.

In discussing this question it will, perhaps, be simpler to make the comparison between Great Britain and America, for the reason that Great Britain has so long been recognised as the foremost manufacturing country in the world, and obviously the reasons which would explain why America has succeeded in competition with her will apply still more strongly to nations which hold inferior positions in the industrial world. One reason, which seems to be agreed upon by both British and American writers, is that the tendency in American manufacturing is toward standard articles, with the consulting engineer playing a secondary part, while in Great Britain the tendency has been rather toward a special design for each case, with the consulting engineer ruling supreme. It is one of the funda-

mental principles of successful manufacturing to adhere to standard sizes, which enables special machinery to be used for particular operations, with the result of turning out the product both cheaply and expeditiously. This is not an American discovery, but the fact remains that Americans have been the ones to adopt it on by far the largest scale and to carry it into all lines of manufacture. This principle is, doubtless, carried out more or less fully with relatively small articles everywhere, but in America it extends to such large structures as bridges and locomotives, which were, in fact, those which aroused the keenest interest in Great Britain on account of the purchase in the United States of the bridge for the Atbara River, in the Soudan, and also some American locomotives for use in Great Britain itself. In both cases the award to American manufacturers was not on the score of being the lowest bidders, but principally on account of quick delivery, and this was possible largely on account of the facilities for turning out standard articles.

In certain lines it would seem that the reason for American advancement is the greater readiness to attack engineering problems on a very large scale, as shown by the award of contracts in Great Britain to American firms for large steam engines and dynamos. American manufacturers seem to be ready to respond to any demand for work in their line, however great the size. This is shown in the United States by the huge units for the Niagara Falls power station, the Boston Elevated Railway, the Third Avenue Railway, of New York City, and the Metropolitan and Manhattan Railroads, of the same city, the units in the latter being of five thousand kilowatts, — the largest ever designed. American firms have supplied the machinery for the Metropolitan lighting station in London, and are to supply that for the great municipal railway system of Glasgow.

The story of the invention of valve gear for steam engines to dispense with the tiresome work of opening the valves by hand is very familiar, and suggests what has been another cause for the peculiar condition ruling in American manufacture, namely, the necessity of doing by machinery what is either very laborious and irksome if done by hand, or to make up for lack of sufficient manual labour by accomplishing the result by machinery. In a new country like America, which offers such prizes for energy and ambition, there is a condition different from that prevalent in the older countries of Europe, where the petition in the Book of Common Prayer " that we may be made content with our station in life " seems to be a thoroughly natural one.

In America the petition is exactly the reverse. Every ambitious boy and young man who is not highly placed at the beginning, feels that in time, with any sort of good fortune, he will certainly better his condition. This has been due both to the absence of a dense population and to the opportunity to strike out into a new country, and also to the fact that there is neither titled nobility nor aristocracy to look down upon trade and frown upon a man who has once worked with his hands. Indeed, it is a proud boast of the Americans that they are a nation of mechanics.

Closely connected with this idea is another, that American business men are more ready to engage in new enterprises which promise good returns than those of Great Britain, from the fact that a vastly greater number of wealthy men in the United States have made their own fortunes than is the case in the older countries, where the large fortunes, as a rule, are inherited. The training which comes to men who have gained their own wealth is obviously a tremendous advantage, and one not likely to come to the man who starts in with wealth and an established business, and whose aim is rather to conserve what he has than to strike out along new lines. The natural resources of America are so great and so diversified that they invite an enterprising race to exploit them, and the population from the very start has been very largely of this class. It must be remembered, too, in this connection that while the bulk

of the population in early days came from Great Britain, there has been a steady stream of immigration from all the European countries, with the natural benefit of the interaction of the different races on one another, and the final production in their descendants of a race which, while pure Aryan, is still a mixture of the different branches and seems to have retained the good qualities of all.

Sight should not be lost of the fact that although the European countries have been manufacturers for a much longer period, power manufacturing is just as old in America as in Europe, because the steam engine was adopted in America almost as soon as in its perfected form, and, indeed, along some lines American practice led the way; moreover, the conditions in America were such that it became necessary to solve problems which were different from those in Europe, and the self-reliance of a scanty population in a new country led to the development of types which were, and have remained, distinctively American, such as the walking-beam engine on the Eastern rivers of the United States and the stern-wheel boats of the shallow Western rivers. The same thing has been true of the development of railways, and while there have been British critics who could see nothing good in the American locomotive, the fact remains that the development along American lines has given a railway mileage greater than that of the whole of Europe, along with such safety devices as the air brake and such means of comfort as the Pullman sleeping and drawing-room cars. This ingenuity and readiness to attack new problems, as well as a disinclination to consider anything, however good, as final, has naturally placed American manufacturers well to the front, and, indeed, ahead of those of other countries where intense conservatism is the rule.

Americans are justly proud of their skill as handicraftsmen and the ingenuity of the native-born American mechanic; but it would be a very superficial study which overlooked the fact that a large percentage of the mechanics in American shops are of foreign birth, who have brought to these shops the benefit of the skill and training they had acquired in their old homes. Moreover, it is probably not unfair to assume that these foreign-born mechanics are above the average of those left at home, for the very reason that the enterprise and progressiveness requisite to make a man break up his home ties and go to a new country are such as would make a man the best workman among his fellows. If this estimate be true, it would mean that the American shops have not only the benefit to be derived from the greater skill of the native-born workman, but also that of the better men from the European shops, thus leaving the latter at a distinct disadvantage.

The greater opportunities for advancement which exist in America have also had a marked effect on the workmen, for the reason that a man who feels that he may, by industry and close attention to his work, some day become a manager or proprietor, will be a more zealous and faithful workman than one who feels that his place in life is settled and that his aim is simply to have as good a time as he can and get the greatest amount of pay for the least exertion, rather than, as is the case in well-conducted American shops, of getting out the largest product and earning the largest wages in a given time.

The question of technical education is one that has been discussed a great deal, and the opinions expressed seem to depend very largely upon the personal bias or experience of the writers. This alone is a very large subject, and it seems to the writer to have very little weight in this particular question, for the reason that as industrial America draws on the whole world for the rank and file of her army, she gets the benefit of the best that is done in this line in all countries.

The old saying that "one swallow does not make a summer" is applicable in the discussion of this question of the position in the industrial race, and it would be misleading and untrue to claim for America that because, in certain

lines, she is at present ahead of other countries, the same is true for all; indeed, in many lines of work the position which a country takes seems to be due more to a few individuals of exceptional talent than to any special conditions in the country as a whole. This is noteworthy in the case of vessels of the torpedo-boat class, where Thornycroft and Yarrow in Great Britain, Normand in France, Schichau in Germany, and Herreshoff in America have all done exceptional work, and it seems in every case to have been due to some one individual in these firms.

In the case of the Herreshoffs, for example, Mr. Nathaniel Herreshoff has been described as an "engineering genius," and the same is true of Mr. J. A. Normand, the success of whose boats is, undoubtedly, due to his own remarkable engineering talents. Mr. Yarrow's record is so well known to all engineering students that the reason for the remarkable success of his work is clearly due to himself, and the same is true of Mr. Thornycroft. In America there is a very notable instance of the effect of a strong personality in the great Westinghouse industries, the success of which, as is well known, is due almost entirely to the engineering talent, business sagacity and courageous foresight of Mr. George Westinghouse. No one man, of course, could carry out the details of such vast enterprises as are associated with his name, and he has surrounded himself with younger men of ability who ably second his initiative; but it is his hand which guides the general policy, and it is surprising to learn of his intimate acquaintance with all of his enterprises. Other famous names occur to the reader in all the great industrial countries, such as Whitworth, Armstrong, and Vickers in Great Britain, Schneider in France, Krupp in Germany, and Ansaldo in Italy.

In spite of the strong influence of personality on industrial success, it still remains true that generally success will depend very largely upon the absence of hindrances or upon the freedom to follow those methods which are obviously essential to success. In the older countries there is not such great freedom as in America, as far as the proprietors are concerned, on account of the greater weight given to vested interests and a lack of the inducement to engage in business enterprises which often exist in America. British writers have mentioned more than one instance where a promising business has been throttled by absurd restrictions designed for a totally different condition of affairs than those in force to-day. Again, in America it is not at all uncommon for a business enterprise to be presented with the land for its factories, and a handsome bonus in addition, for locating in a particular place,—something which is almost unheard of elsewhere.

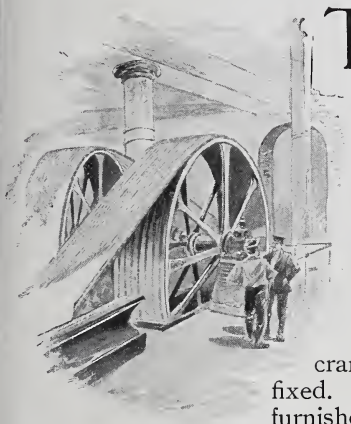
Another very important matter on the labour side of the question is the difference in the attitude of trades unions in America and other countries, especially in Great Britain. While many of the aims of the trades unions in America are the same as of those in European countries, and while in many cases the demands of the unions are, unfortunately, utterly unreasonable and would ruin manufacturing if granted, it still remains true that in the lines of work demanding the higher grades of intelligence there have never been such unreasonable strikes as the one which began in Great Britain in the summer of 1897, commonly known as the "Engineers' Strike," and which after six months led to the ignominious defeat of the unions. It is most unfortunate that there should be serious disagreement between the employers and their men, and, as a rule, proprietors are willing to grant reasonable demands. The really deserving and reasonable men in the unions can almost always obtain what they ask for; but the trouble, when a strike comes, is that the less deserving element gains the control and utterly ignores the fact that the employers have the same right to protect their interests that the men have to protect theirs. In America it does not seem to take as long for the men to appreciate this as it does abroad, and this, undoubtedly, is an element in America's success. No attempt has

been made to discuss such questions as the superiority of American tools and methods of shop organisation, because the most progressive European proprietors are adopting them very rapidly, and if this becomes general, the question of which is to come out ahead in the race would be settled by the natural resources of the country, the efficiency of labour, and the general aptitude of the particular nation. In these days of constant intercourse of the people of all nations and the dissemination of the latest ideas through the technical press, it is simply a question of the adoption of the best ideas and the turning of them to profit by the great captains of industry.

An American might readily be pardoned for believing that, with all the advantages of his country, both in her natural resources and her people, she is destined to obtain a decided supremacy; but whether this be true or not, there can be no question that America will be one of the leaders in the industrial world and second to none.

TYPICAL HORIZONTAL BRITISH STEAM ENGINES

By W. D. Wansbrough



THE horizontal steam engine in the primitive form still commonly employed for small uses, and occasionally met with in the larger sizes, consists of a flat bedplate upon which the cylinder and crank pedestals are fixed. The cylinder is furnished with a single slide valve driven by a fixed eccentric; the governor acts upon a throttle valve in the steam pipe; and the piston-rod is guided by two or four detachable slide bars. These are the bare essentials of a steam engine,—the skeleton, in fact, from which has been built up the highly organised machine which has become the settled type conformed to, with but little variation, by the leading engine builders.

In this rudimentary steam engine, again, the cylinder is large, comparatively speaking, in diameter, and of short stroke; the crank shaft is surprisingly small in diameter; the main bearing is necessarily short, because of the necessity for keeping the steam passages of reasonable length; the steam pipe comes down from above, and the exhaust pipe goes straight up through the roof of the engine house.

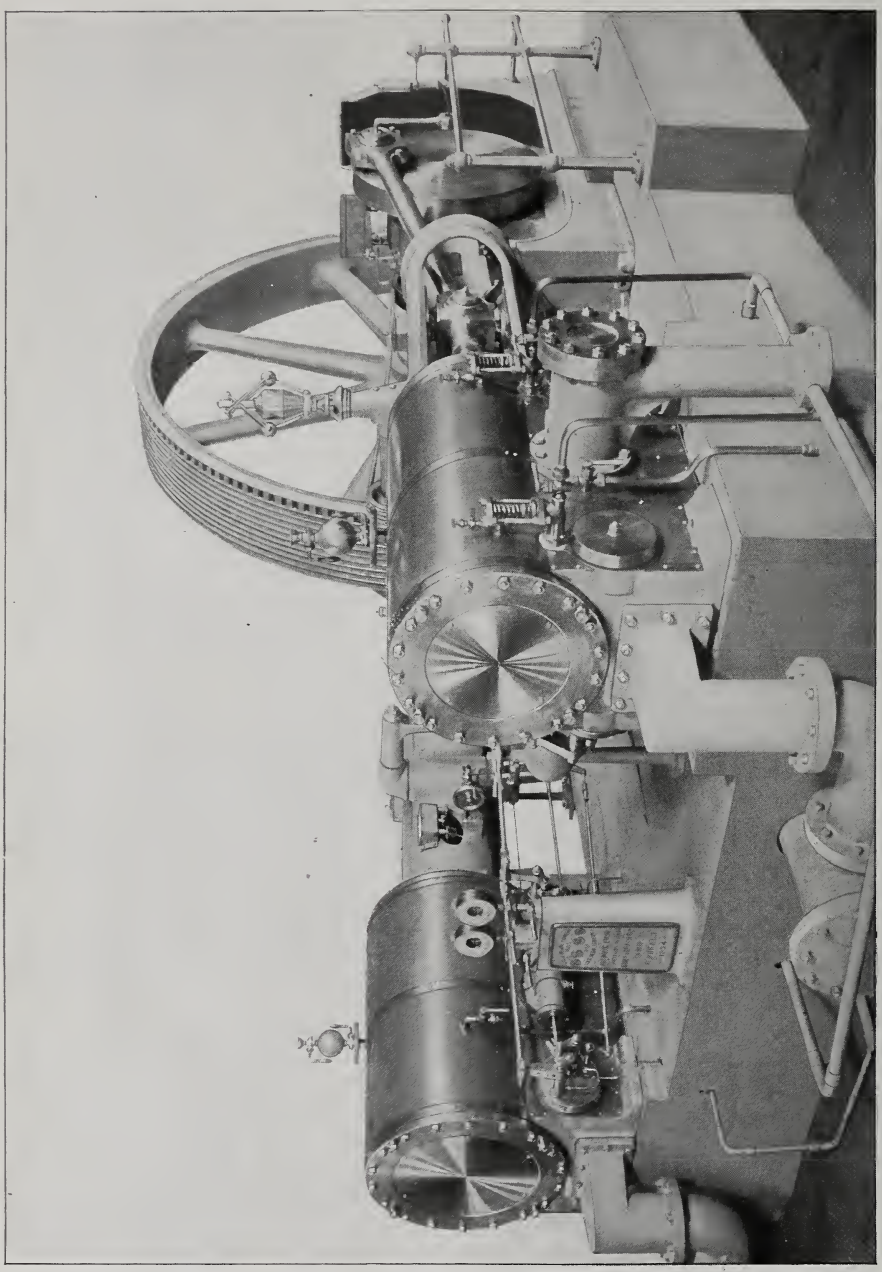
"No complications about my engine," says the owner, complacently—"good, solid, substantial job. Does all my work with 50 pounds pressure. What is the matter with it?"

The difficulty is to say what is not the matter with it! The old cast iron 64-pounder cannon is not more unlike the 6-inch quick-firer of to-day than is this antique machine compared with a modern horizontal engine of the highest class, as the following pages shall testify.

A very casual glance at the examples of recent practice by well-known British makers which illustrate these pages will reveal the fact that nowadays we begin to design engines from the crank shaft instead of from the cylinder. This is, of course, directly at variance with the old-established system which makes the diameter of cylinder the governing factor in all the dimensions of the engine. That there is, however, no fixed relation between the diameter of the cylinder and the diameter of the crank, even for a given steam pressure, is easily demonstrable.

The cylinder dimensions given, the number of expansions and the speed, are, of course, determined with reference to the load, while the diameter of the crank shaft is derived from the weight of the fly-wheel or other revolving mass, which, in its turn, is a function, not so much of the actual load as of the inequalities in the turning effort at the crank pin and the percentage of governing accuracy required, as will presently be seen.

The permissible load per square inch of main bearing varies between rather wide limits, according to the experience or fancy of the designer or his client; but there appears to be a constant tendency towards increasing the amount of bearing surface per unit of load, and rightly, for the main bearings are, perhaps, the most vital part of the engine. An abundance of bearing surface provided in the first instance will eliminate many of the worries incidental to the starting and maintenance of the engine, and much will be forgiven to the contractor whose engines may be relied



COMPOUND ENGINE BUILT BY MESSRS. DANIEL ADAMSON & CO., DUKINFIELD.

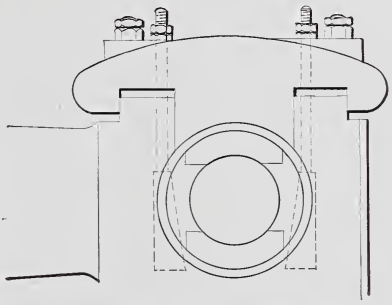
upon to run their appointed time without even an "ease-down" on account of the main bearings feeling a shade warmer than usual.

The foundations should be broad and deep to avoid the slightest alteration in level through settling under the heavy live weight they have to carry. With a view of affording a substantial basis for the main plummer blocks, a pattern has recently come into use in which the feet or bases of the main bearings have been spread out to an extent which gives a first impression of the engines being principally made up of fly-wheel, shaft, and plummer blocks to which a pair of cylinders with trunk guides have been hitched on as a necessary, but subordinate, part of the structure. Nevertheless, these broad bases, planed on the under sides, and spreading over a considerable area of the masonry, secure (as far as it lies in the power of the engine-builder to secure), that the engines, once erected true and square, shall remain so, unless disturbed by an earthquake, as long as the engines endure.

The construction of the actual plummer block has settled down into practical uniformity, and varies but little from the type indicated by the sketch on this page. The deep gap in the jaw is spanned by a massive cap, which, taking its bearing on the outer edges of the jaws, effectually closes and secures the gap. The "brasses," usually of bronze or cast iron, lined with some anti-friction alloy, are built up of four parts dovetailed, or, rather, "joggled" together. Vertical adjustment is secured by screwing down the cap, and horizontal adjustment by drawing up the side wedges. These wedges bear against corresponding inclined projections on the sides of the "brasses," the four parts forming a solid circular bush when cap and wedges are pulled up tight, but capable of being easily withdrawn for examination. The lubrication is very commonly effected by means of a small rotary oil pump which circulates a quantity,—a few gallons,—of oil continuously through the bearing.

When the latter is of the ample proportions now usually adopted, a thin film of the lubricant is maintained between the fixed and revolving surfaces, so that the journal may truly be said to float in oil. It is evident that so long as this is the case, wear is impossible; and, as a matter of fact, it is quite usual for an engine to run for several years without the main bearings ever being opened out, even for examination.

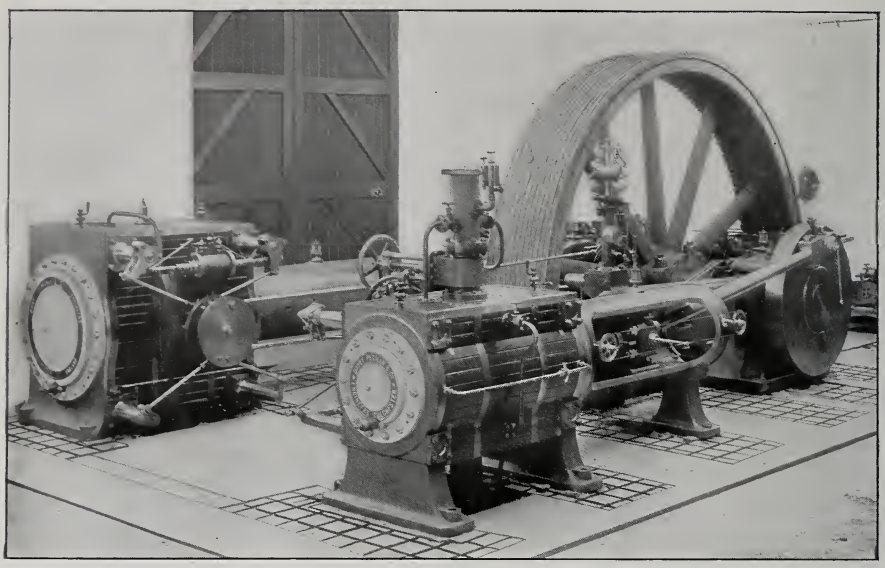
It will be observed that in all, or nearly all, the engines illustrated in these pages, the connection between the main plummer blocks and the cylinders is formed by a tubular frame or girder in the direct line of stress. The advantages of this direct and rigid connection over the old flat bed-plate, in which the metal is disposed most unfavourably for resisting the stresses imposed upon



STANDARD FORM OF PLUMMER BLOCK

it, are immediately evident. Thus, during the outward stroke of the engine the great surface of the old bed-plate tends to become convex in form, and correspondingly concave during the inward stroke. This tendency is, of course, resisted by the foundation bolts which unite the bed-plate firmly to a mass of stone or concrete. In the tubular or trunk bed, on the contrary, these alternating stresses are taken up in the engine frame itself.

Structurally speaking, the cylinder is simply a continuation of the trunk, the junction between the two being formed by strong flanges bolted together, a dowel, or projecting rim, on the end of the trunk entering the cylinder for the purpose of securing centrality. At the end of the trunk guide nearest the main bearing there is, or should be, a foot,



A COMPOUND CORLISS ENGINE BUILT BY MESSRS. DAVEY, PAXMAN & CO., LTD., COLCHESTER

resting upon the masonry foundation, and well secured to it, for the purpose of taking up the downward pressure of the crosshead, or the upward pressure if the engine happens to run "inwards." The effect of this pressure (which is, at mid-stroke, very nearly the total pressure on the piston, multiplied by the ratio of crank to connecting rod), is not always provided against.

But the greatest direct stress upon the tubular girder frame is, undoubtedly, that caused by the accidental pressure of water in the cylinder at the moment of starting the engine. If the steam admission valves are of a type which cannot be lifted by excess of pressure from within, each cylinder should be fitted with spring relief-valves of large size loaded to just beyond the initial steam pressure, and placed at the lowest available point. The exhaust valves, it is true, drain the cylinder, but just before the crank passes the centre, when the exhaust valve has closed and the steam valve has not yet opened, a body of water may be shut up in the cylinder and something has to go. Usually in such cases, if at the front end of the cylinder, the piston-rod cotter gives by shearing; if at the end furthest from the crank, the piston-rings are forced inwards or the cover may break. If, however, a quantity of water, owing to traps or bends in the steam pipe, be carried over into the cylinder while the engine is running at speed, the shock is pretty likely to snap the girder in two close to the plummer block before the piston has time to give way.

From the misfortunes of others we learn not to make the cylinder a trap for water between a descending steam pipe and an ascending exhaust pipe; nor to allow the condenser to take its water (if it can be avoided) from a level higher than itself.

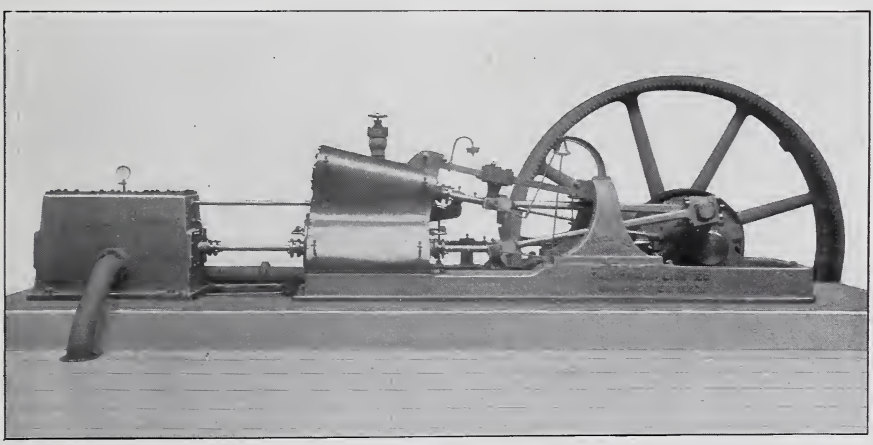
We turn now from the fixed parts of the engine to the chain of moving parts by which the steam pressure is transmuted into rotative power. Regarding the piston, it is unnecessary to say more than that, for obvious reasons, it should not be too strong, and that the body should be deep enough (*i. e.*, should present sufficient bearing surface) to carry its weight, even in the absence of a tail-rod, without injury to the bore of the cylinder. The rings should be uniformly pressed radially outwards with no more force than is sufficient, while following up the wear, to resist the tendency of the steam to leak past between the rings and the cylinder. The

rings should also be pressed laterally against the back and front flanges of the piston to the avoidance of rattle due to slackness sideways. Cast iron rings are almost universally employed. Every engine builder has, however, his own method of piston construction by which he is prepared to stand or fall, and there are, in addition, numerous firms whose sole business it is to make and sell pistons of patented design. In this connection it is well to remember that simplicity in piston details is a desideratum.

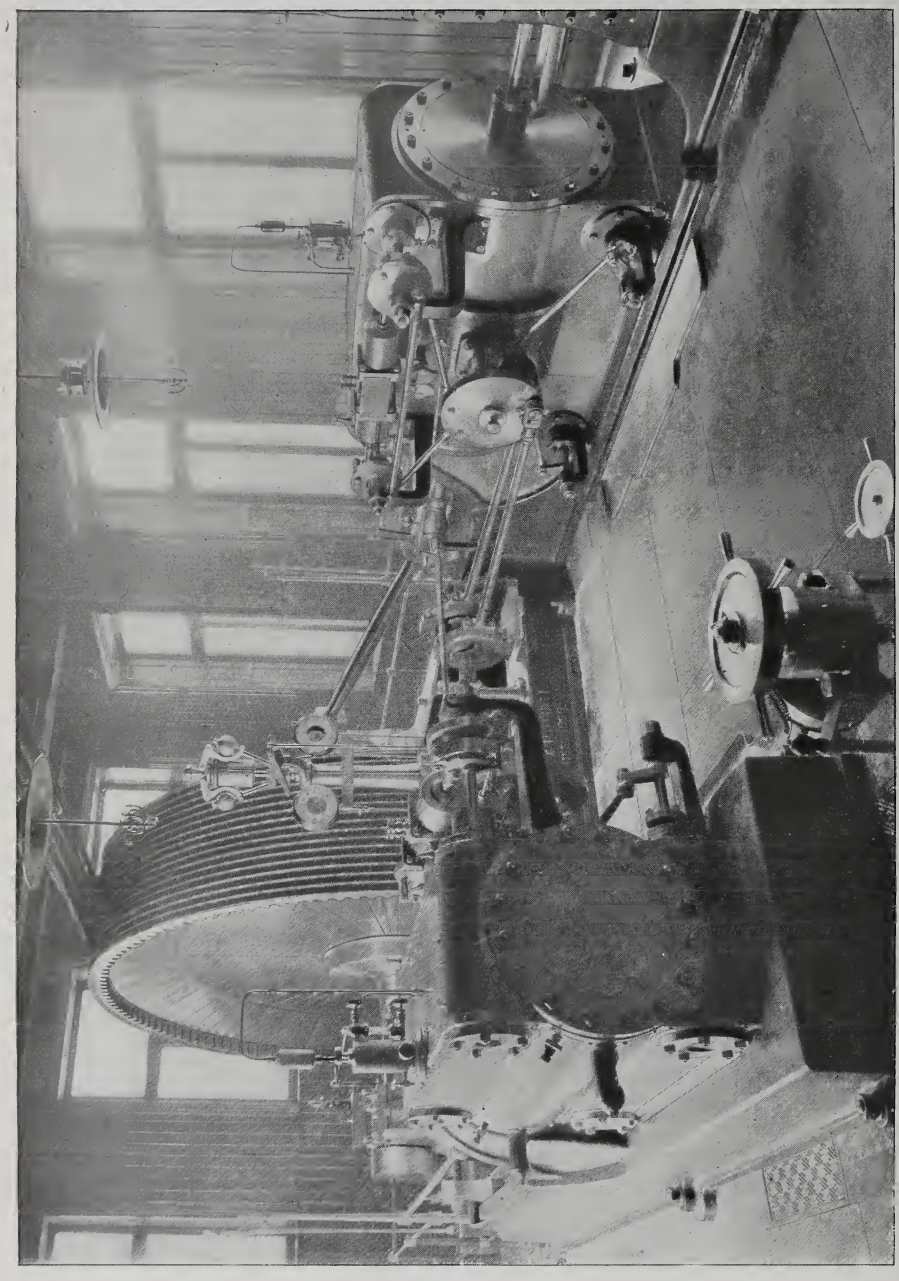
The piston-rod, always of mild steel, is usually tapered at both ends, cottered into the crosshead, and secured by a large and deep nut behind the piston. A forcing-off nut next to the crosshead is a convenience. The sectional area at the cotter hole practically determines the diameter of the rod, which is then always strong enough to resist crushing or bending.

The crosshead itself is usually a box-like steel casting, with bosses for the reception of the piston-rod end and the crosshead pin, and is fitted with cast iron slipper blocks. The guide surfaces of the trunk are almost invariably bored out to a circular cross-section, as a rule by a special machine, which also faces up the flange for jointing to the cylinder and bores out the jaw of the plummer block at one operation. This simple and cheap method of construction is rapidly supplanting the flat guide surfaces formerly employed. Perhaps the best and safest method of taking up wear in this class of crosshead (which, with reasonable care, should never occur) is by inserting very thin sheet brass liners between the crosshead block and its slippers. All risk of unequal setting up is thus avoided; and wedges or inclined planes for this purpose may be considered obsolete. An injudicious zeal in setting up crosshead slides may do in a few minutes what years of ordinary wear would fail to accomplish.

The crosshead pin, which is embraced by the small-end brasses of the connecting-rod, is prevented from working loose in the sides of the crosshead by an ingenious and simple arrangement. The holes on both sides of the crosshead are bored conically, the larger diameters being outward, and the pin is correspondingly tapered at one end, whilst the other is fitted with a loose split sleeve or ferrule, conical externally. Upon tightening up the lock nuts with which this end of the pin is fitted, both cones are pressed well home, and the centrality and tightness of the pin secured. The practice adopted by some makers of flattening the crosshead pin at the top and bottom appears to be better adapted for vertical than for horizontal engines, as the weight of half the rod in the latter case is not



A SUPERPOSED COMPOUND ENGINE BUILT BY MESSRS. GALLOWAYS, LIMITED, MANCHESTER



COMPOUND CORLISS ENGINE BUILT BY MESSRS. WOODHOUSE & MITCHELL, BRIGHOUSE, YORKS

25'5'85

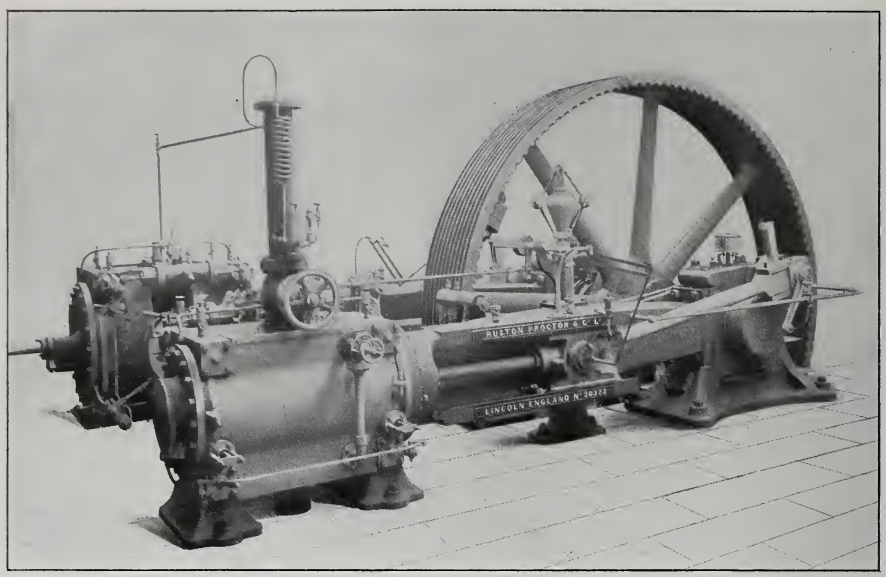
supported by a cylindrical surface. The same object is better attained by cutting away a corresponding amount of the interior surface of the brasses. This small-end bearing of the connecting-rod has a rather trying duty to perform, for two reasons:—firstly, owing to the conduction of heat from the piston-rod; and, secondly, owing to the nature of its movement, which is very different from the smooth, continuous motion of the crank-pin within the large-end brasses. The size of the crosshead pin is not always adequate to the work it has to perform. It should always be automatically lubricated by a licker or other arrangement of oiler, as it does not generally receive its due share of attention if it cannot be oiled while the engine is in motion.

The advantages of a long connecting-rod in every situation where its use is practicable need not be enlarged upon. In the case of the horizontal engines here considered there is full scope for any length which appears to be desirable; and although the writer has not the actual figures before him, it is safe to say that in general practice the rods do not differ appreciably from five cranks in length. Again, in the connecting-rod the element of weight is an influence for good, particularly with the balanced disc form of crank, and there is no reason whatever for adopting any but liberal proportions.

There is rather a want of uniformity in British practice as to the construction of the large end of the connecting-rod. There is the marine type, in which the end of the rod is formed into a large jaw, having a precisely similar loose jaw bolted up to it, the pair embracing the brasses which are circular externally. There is also the rod with a loose strap secured only by the gib and cotter; and, again, there is the rod with strap secured, as in locomotive practice, to the butt end of the rod by bolts. Finally, there is the solid-ended rod, precisely similar to the last-named, except that the strap is formed in one piece with the rod, necessitating the use of a loose collar on the crank-pin, as the brasses must be taken out sideways. In the two latter cases, the cotter is not charged with the duty of keeping the strap from parting company with the rod, and is, perhaps, more properly described as a wedge, the brass being formed with an inclined projection to match on one of its sides. In a solid-ended connecting-rod (and the principle may be carried out at both ends) even though the cotter should go adrift, the brasses cannot get away, and the danger of a total smash is very much lessened.

Lancashire-built engines are mostly fitted with wrought iron or steel cranks, finished bright all over; otherwise, the use of the balanced cast iron disk is all but universal. In either case the shaft and crank-pin are secured by being forced in, or the crank and disk is put on hot and fixed by contraction. In all cases keys are employed in addition. There is probably little to choose between the disk and the crank; the former admits of the crank, pin, and connecting-rod end being counterweighted without offending the eye by disclosing an irregularly shaped revolving mass. The large flat face of the disk also offers considerable facilities for ensuring that the holes bored for the reception of the shaft and crank-pin are severally and jointly true. The distance from the main bearing to the centre line of the engine is kept down as much as possible by making the crank-pin comparatively short and of large diameter in providing the necessary bearing surface for the connecting-rod brasses. The lubrication of the crank-pin is very simply and effectually secured by the use of a small tubular return crank, which enables oil to be fed in from a fixed drop-feed lubricator while the engine is running. This is a most valuable addition to the comfort of the attendant, who is relieved from all fear of his oil cups becoming exhausted before the hour for shutting down.

In engines of any size where the power is taken from the rim of the flywheel, rope driving is now almost universally employed in Great Britain. The power which may be transmitted by a rope drive increases directly as the speed



A COMPOUND CORLISS ENGINE, WITH FLY-WHEEL GROOVED FOR ROPE DRIVING. BUILT BY MESSRS. RUSHTON, PROCTOR & CO., LTD., LINCOLN

up to the point at which the centrifugal force, due to the weight of the rope itself, begins to diminish its grip of the *V*-shaped groove in which it runs. After this turning-point in the adhesion of the rope, its efficiency rapidly falls off. It is stated, upon good authority, as the result of careful investigation, that at speeds of 4200 feet per minute, and at 5200 feet per minute the efficiency is just equal, the point of maximum efficiency occurring at between 4700 and 4800 feet per minute. As the strength and the weight of the rope bear a constant relation to each other, this value holds good for all sizes of ropes.

The peripheral velocity of fly-wheels is usually calculated with more or less reference to this critical speed, and the weight of the rim is then deducted by a well-known method which provides that the irregularities in the propulsive pressure upon the piston, as exhibited by the indicator diagram (after being corrected, firstly for the inertia of the reciprocating parts; and, secondly, translated from piston pressures into crank-pin pressures), shall be absorbed by the fly-wheel without causing its angular velocity to vary more than a certain predetermined amount above or below the normal. In electrical work the ratio between the maximum variation per revolution and the mean speed in some cases is required not to exceed $\frac{1}{250}$, which means that an enormously heavy revolving weight is required, with strength of shaft and bearing surface in plummer blocks to correspond. There is a very close connection between the weight of the fly-wheel rim and the sensitiveness of the governor, about which more presently.

Up to about 16 feet diameter the fly-wheel is sometimes made just as a large pulley, in halves, bolted together at the boss and rim; or if very broad, it may be composed of two distinct wheels bolted together by peripheral flanges, the halves, of course, breaking joint with each other. Larger wheels (and smaller ones, too, sometimes) are built up of six, eight, ten, or more segments, the arms, of circular section, being cottered into parallel holes bored radially in the boss. The arms are connected to the rim at the joints by square flanges, which thus assist in holding the segments together.

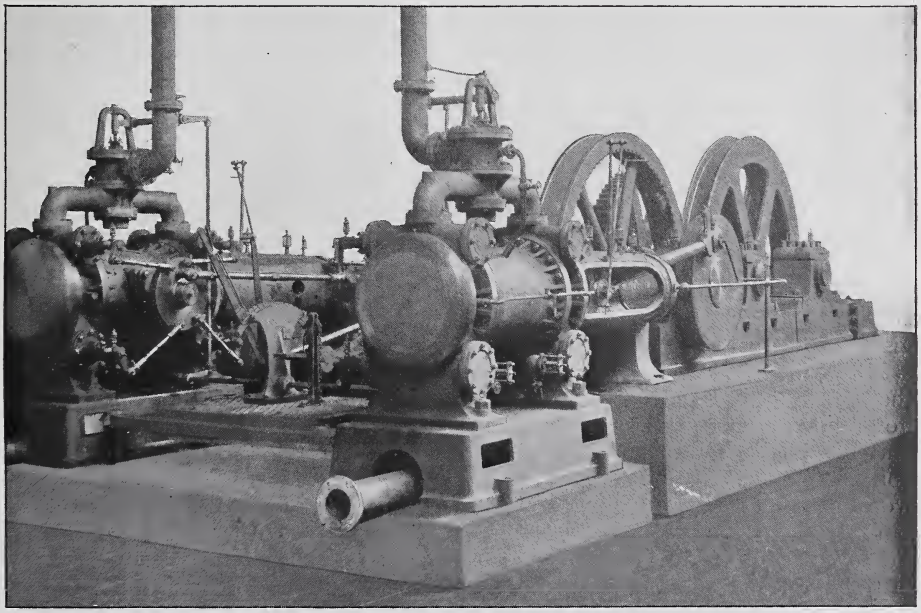
About 80 feet per second are usually assumed as the limit of safe speed for a

cast iron fly-wheel, and it will be noticed that this corresponds very nearly with the speed at which a cotton rope is at its maximum efficiency. The angle at which the sides of the *V*-grooves in rope-driving wheels are inclined to each other is about 45°.

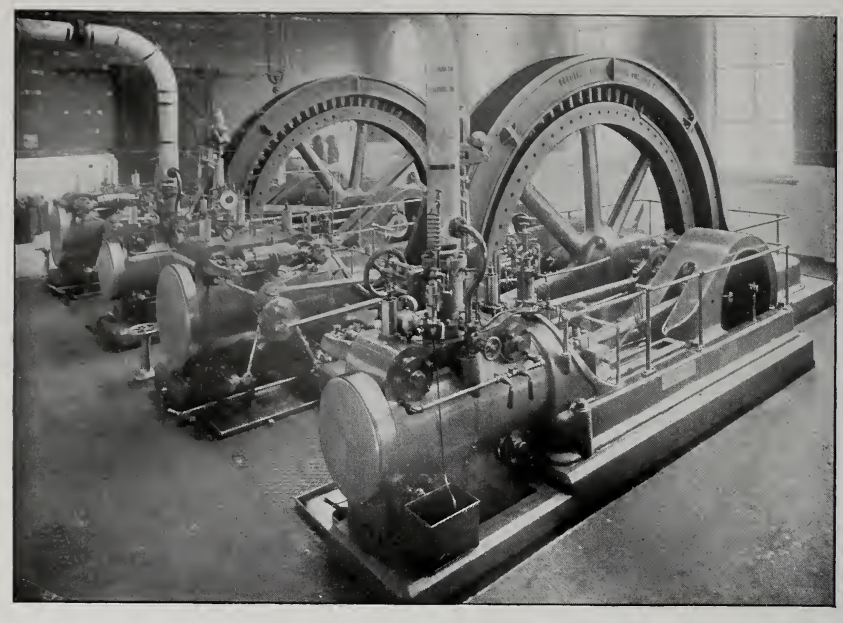
In looking over the representative engines which illustrate this article it appears that the predominating type of governor in use in Great Britain is the Porter, or loaded, high-speed governor, the several details varying, of course, amongst the different makers. In some of the illustrations spring-loaded governors, of types peculiar to the respective makers, will be observed, and in one case, the governor of Messrs. Galloways, Limited, the "balls" are rollers as well as weights, and the lift of the governor-sleeve, relatively to the extension of the weights, is determined by the angle of the inclined planes formed in the peculiarly shaped central weight. There is little room for doubt that in every one of these governors such care in design and adjustment has been exercised as to ensure a very close approach to accurate regulation of speed in the engine.

Instead, however, of attempting to describe each of them in detail, which would be unnecessary and out of place in this article, the space may be better occupied in a glance at the actual conditions which have to be fulfilled before we can expect steady and accurate governing. Excluding the original Watt, or non-loaded governor, there is one feature common to all these systems, however diverse they may be in detail and appearance; and that is that the resistance at every point in the lift of the sleeve must bear a definite relation to the centrifugal force resident in the revolving weights in their corresponding position. The increase in the centrifugal force as the orbit of the weights enlarges may be met by the progressive resistance of a spring; or by the link-work of the Porter governor, which is so proportioned that the balls act upon the central weight at an increasing disadvantage; or by the inclined planes in the Galloway governor, which perform the same office.

Now, if the resistance keeps pace exactly with the centrifugal force, we shall have a governor of which the forces are



A WINDING ENGINE, WITH CORLISS VALVES AND GEAR. BUILT BY MESSRS. ROBEY & CO., LTD., LINCOLN



A SET OF DIRECT-CONNECTED ENGINES, BUILT BY MESSRS. POLLIT & WIGZELL, LTD., SOWERBY BRIDGE

perfectly balanced at all points within its range,—the governor which embodies the ideal of the writers on mechanics. It is, however, a perfectly useless governor in practice. But assuming, for the sake of illustration, that the resistance provided is a spiral spring with an adjustment for compression, a very slight reduction of the pressure on the spring, and the governor,—which previously had been flying from top to bottom at the slightest alteration in the speed of the engine,—becomes steady, its oscillations become slower and less frequent. Further reduction of the pressure upon the spring results in increased steadiness; more still, in sluggishness.

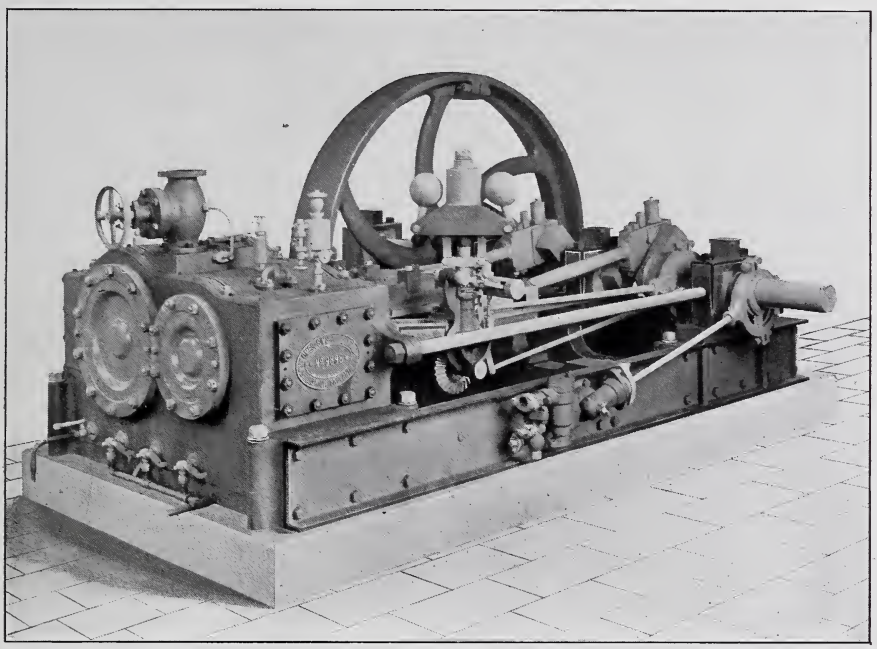
Now comes in the connection between the fly-wheel and the governor. Fine governing demands a sensitive governor, and a sensitive governor would be in continual movement unless the fly-wheel were heavy enough to absorb at one part of the stroke, and restore at the other, the variation in the turning effort at the crank-pin, already noticed.

If the work to be actually performed by the movement of the governor, as in altering the valve gear to a different cut-off point, requires the exercise of any force, as the movement of a heavy link, for example, the size or the speed of the governor may be increased to any extent. As a rule, however, governors upon such engines as are here considered, although they spin, toil not at all; their functions are confined to setting a trap, as it were, into which the valve gear falls at the exact point in the stroke required to keep the engine moving at the proper number of turns per minute.

And now we come to the cylinder. Speaking generally, with two or three notable exceptions, the four-valve Corliss cylinder is the type most prevalent in Great Britain for the class of engine considered. This cylinder is made up of four parts, viz., the actual working barrel or liner; the outer casing, or jacket; and two end castings, containing the admission and exhaust valves, and extending downwards to the foundation, forming feet or bases, through which not infrequently the exhaust steam passes on its way out. This construction is convenient in many ways, as the tool work re-

quired is plain boring and turning, and it enables cylinders of large size to be quickly dealt with. The castings also are intrinsically simple and there is little risk of defective work.

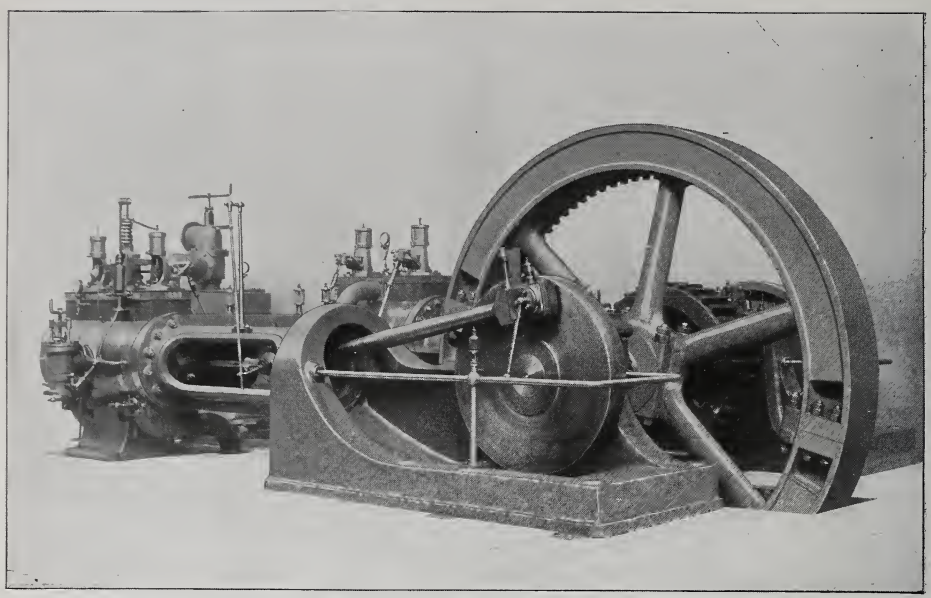
The proportion existing between the stroke and the diameter of a high-pressure cylinder is a matter of compromise. With a given volume of cylinder the adoption of small diameter and long stroke helps to reduce the losses due to clearance. The smaller the piston, and covers also, the less is the effect felt



A COMPOUND ENGINE, BUILT BY MESSRS. RANSOMES, SIMS & JEFFERIES, LTD., IPSWICH

which those surfaces exercise in absorbing heat from the incoming steam and giving it up again during the return stroke to the exhaust. But inasmuch as any addition to the length of cylinder, if we retain the 5-crank length for the connecting-rod, means an addition of three and one-half times that amount to the total length of the engine, it will be easily seen that length of stroke, if carried beyond moderate limits, materially influences the cost of the engine. In good practice for horizontal engines it is usual to make the stroke from two to two and one-half times the diameter. The relative volumes of the two cylinders of compound engines vary according to the steam pressure used, and depend also upon the fact whether or not a condenser is employed. It is usual, for convenience of manufacture, to standardise the diameter of the low-pressure cylinder, and to modify the diameter of the high-pressure one to suit the special circumstances of the case, the object being, of course, to secure equal power from the two cylinders. Roughly speaking, the ratios of cylinder volumes are, for non-condensing engines, from 2¼ to 2½ to 1 for steam pressures of 90 to 100 pounds; 3 to 3½ to 1 for 120 pounds; while for condensing engines working at steam pressures of 80, 90, 100, and 120 pounds, the most usual ratios are, respectively, 3, 3¼, 3½, and 4, to 1. Piston speeds may be anything up to 700 feet per minute, and there is a tendency, for electrical work, to go higher still.

Nowadays the horizontal jet con-

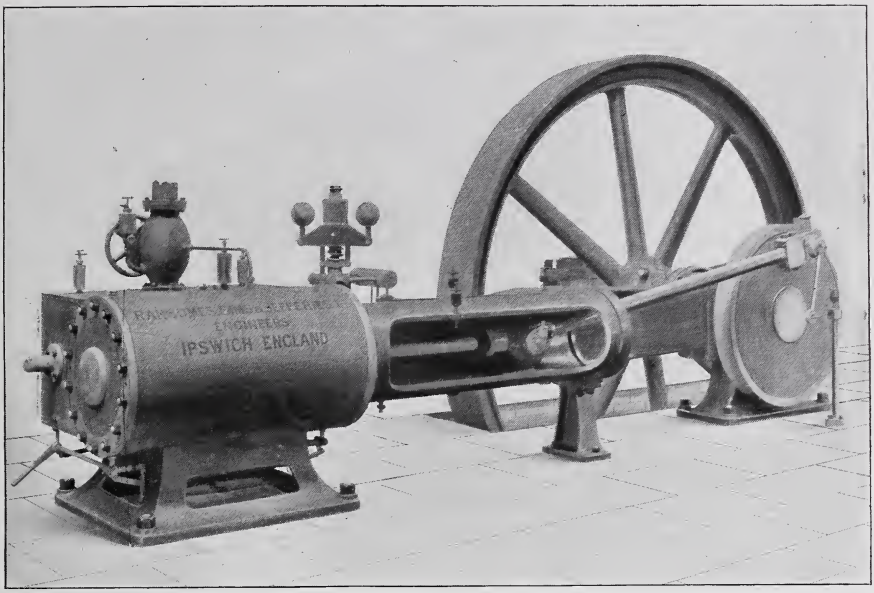


A COMPOUND ENGINE, WITH RICHARDSON-ROWLAND TRIP VALVE GEAR. BUILT BY MESSRS. ROBEY & CO., LTD., LINCOLN

denser, worked by a prolongation of one of the piston-rods, is coming into favour as being more simple, cheaper, and requiring less expensive foundations than the vertical bucket-and-plunger type, while giving equally good results when well proportioned. Surface condensers can hardly be said to be largely in use, except under special circumstances.

If there is one question upon which diverse opinions are held, and sometimes expressed with considerable vigour, in the whole range of steam-engine economy, it is the question of steam jacketing. A steam jacket, supposed, of course, to be supplied with boiler steam, and to be efficiently drained (or it is worse than useless), has an undoubtedly beneficial effect during the outward stroke of the piston; but it is not always remembered that, from the time when the exhaust valve opens and the temperature and pressure of the cylinder-full of steam are suddenly lowered, transference of heat from the jacket steam to the exhausting steam takes place, and this continues during nearly the whole of the return stroke. As the transference of heat is proportionate to the difference of temperatures, far more heat passes uselessly in this way than during the outward stroke when the temperatures within and without the cylinder walls are much more nearly equal. For this reason, while the balance of evidence is in favour of steam jacketing in high-pressure cylinders, it is fairly certain that in the large, low-pressure cylinders of compound and triple engines jacketing is a loss rather than a gain. In this connection it should be mentioned that superheating is being revived, with every promise of practical economy.

The receiver, or re-heater, between the cylinders should always be effectually heated, either by means of an internal coil supplied with boiler steam, or by jacketing, taking care that a steam trap is fitted to the coil or jacket for drainage. The question of drainage in the cylinders has been already touched upon from the point of view of safety; but it is equally necessary for economical reasons that the water in the cylinder, whether brought in along with the steam, or the result of initial condensation, should be got rid of. The bottom exhaust valves, shown in most of the



"LONG STROKE" AUTOMATIC ENGINE BUILT BY MESSRS. RANSOMES, SIMS & JEFFERIES, LTD., IPSWICH

engines illustrated, effect this naturally and thus form a valuable adjunct to safe and economical working. The steam pipe also should be effectually clothed and drained to guard against the inflow of water.

Next we come to the important question of the valve gear. The objects sought to be accomplished in departing from the time-honoured slide valve are:—

Firstly, the practical abolition of slide-valve friction.

Secondly, the independent action of the exhaust valves while the steam valves are under the control of the governor, which is continually changing the cut-off point.

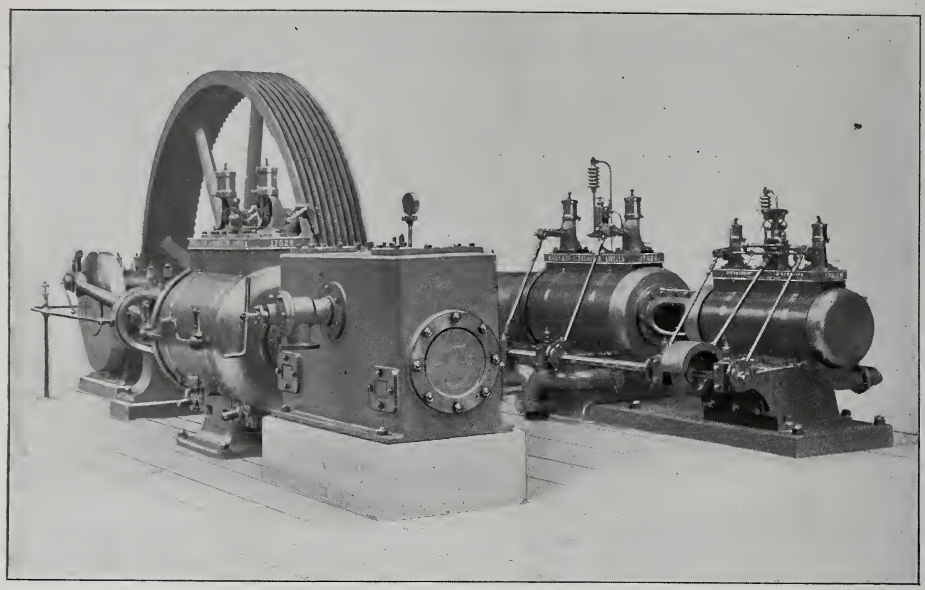
Thirdly, the possibility of greatly reducing the length of the steam passages, thus lessening materially the clearance volume while retaining ample steam-ways in both inlet and exhaust passages.

Fourthly, having the adequate area of steam passage, the valve gear must allow of the maintenance of the boiler pressure (or something very near it) behind the moving piston right up to the point of cut-off, and then shut suddenly at the point determined by the governor.

Fifthly, the exhaust valves must open quickly to a large area, preferably underneath the cylinder, and close as quickly at a fixed point in the stroke.

Lastly, all these motions must be capable of adjustment without difficulty, to give the indicator diagram required; and the valves, while closing suddenly, must not do so to their own injury, for the sake of durability and silence in action.

Any system of valve gear which will fill the above requirements may be classed as good enough for the best engine in existence. There are, practically speaking, two principal systems in use in Great Britain:—the Corliss, or semi-rotating valve, really a slide valve with its working face bent into the form of a circular arc; and the double-beat, or equilibrium drop-valve. In the Corliss gear the four valves, one steam and one exhaust for each end of the cylinder, are alike in construction, differing only in size. The actual details of the valve motion are modified by nearly every



A TRIPLE EXPANSION CONDENSING ENGINE, WITH RICHARDSON-ROWLAND TRIP VALVE GEAR. BUILT BY MESSRS. ROBEY & CO., LTD., LINCOLN

maker, but may be described generally thus:—

Upon a trunnion or stud-pin, fixed to the side of the cylinder, a large flat disk, called the wrist-plate, oscillates through a small arc of rotation, driven by an eccentric on the crank shaft. Four stud-pins, set at suitable points on the face of the wrist-plate, extend to the levers or crank-arms on the horizontal valve spindles. So far as the exhaust valves are concerned, this is the whole of the arrangement. They are opened and shut at the required points by the movement of the wrist-plate.

The connection between the latter and the steam-valve levers is modified by the introduction of a catch or detent in each connecting-rod whereby the steam valves are opened at a fixed point just as the exhaust valves are; but in closing, at the point determined by the position of the governor for the time being, the detent is tripped, or released, and the valves shut with great rapidity through the agency of a small air cylinder, or by a spring. The detent slips into gear again on the return movement of its connecting-rod and opens the valve in readiness for the next stroke. Sometimes a double wrist-plate, having independent movements for the exhaust valves, is employed.

This well-known gear, which was introduced nearly fifty years ago by the late George H. Corliss, is in extensive use in almost every part of the world, but its modifications are so various in the hands of different engine builders that it is practicable to give here only a general idea of its action. The Richardson-Rowland automatic trip-gear, of which the sole makers, Messrs. Robey & Co., Limited, of Lincoln, have supplied the following description, is a very simple and highly successful application of the alternative system, in which equilibrated lifting valves take the place of the oscillating valves of the Corliss arrangement:—

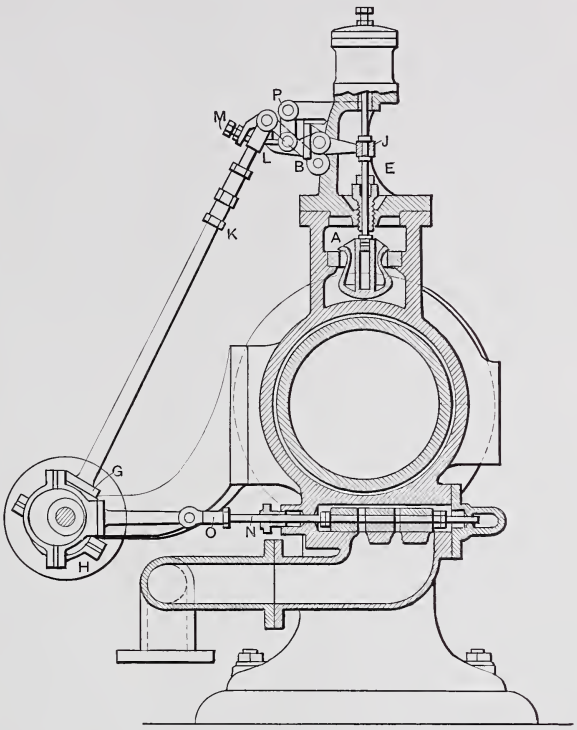
Upon a line shaft, driven by screw gear from the crankshaft, and carried in brackets along the frame of the engine, parallel to its centre line, are placed four small eccentrics, two for the exhaust valves and two for the inlet valves, each set at its appropriate angle.

The cross-section of the cylinder and the enlarged detail of the trip levers on the opposite page show the whole of the gear

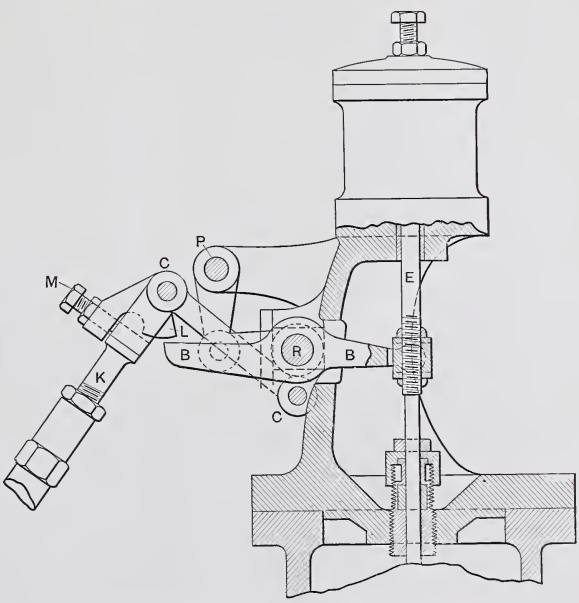
very clearly for one end of the cylinder, the same lettering being applicable to both engravings. The upper end of the eccentric rod *K* moves in an arc whose radius is the link *CC*, and acts upon the valve *A* by depressing the outer end of the lever *BB*, thus raising the valve. This occurs just before the commencement of the stroke. Owing to the difference in the arcs described by the end of the eccentric rod and the end of lever *BB*, respectively, the tripper *L* slips out of contact at a certain point in the stroke, and the valve drops, cutting off the steam instantaneously, the tripper being knocked aside as it passes upwards again.

To prevent the valve being injured by coming down too heavily on its seat, its stem or spindle is prolonged upwards and terminates in a small piston within an air cylinder. A little air-clack at the bottom of this cylinder, or dashpot, regulates the descent, so that the valve falls rapidly, but without concussion. This is the whole of the mechanism concerned in the admission and cut-off of the steam at fixed points in the stroke, and for the low-pressure cylinder of compound engines the cut-off point, when not controlled by the governor, may be varied by screwing in or out the set screws *M*.

In the high-pressure valve gear the governor effects a lateral movement of the fulcrum *R* of the lever *BB*. Thus with the governor at its highest position, the fulcrum *R* would be moved towards the right, in the engravings, to an extent which would prevent the tripper *L* touching it at all; hence the valve would not be lifted and



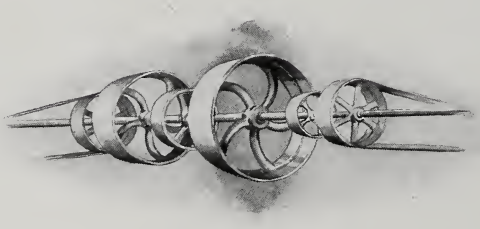
CROSS SECTION OF ENGINE CYLINDER, EQUIPPED WITH THE RICHARDSON-ROWLAND TRIP VALVE GEAR



AN ENLARGED VIEW OF THE TRIP LEVERS

no steam would enter the cylinder. Movement towards the left increases the duration of the admission period proportionately to the height of the governor collar at the moment.

The touch of a finger is sufficient to effect the movement of the fulcrum; hence the governor, though perfectly efficient, is so small compared with the size of the engine it controls as to be almost ludicrous in appearance. The exhaust valves are flat gridiron, or multiple-ported, slide valves, and are so clearly shown as to need no description. Considerations of space prevent any discussion of the economical performance which may be expected from engines constructed in accordance with the points here enumerated; but the examples of modern high-class steam engines which illustrate this general description may be taken as fulfilling very closely the conditions which make for economy in working and maintenance, so far as they are known to us at the present time.

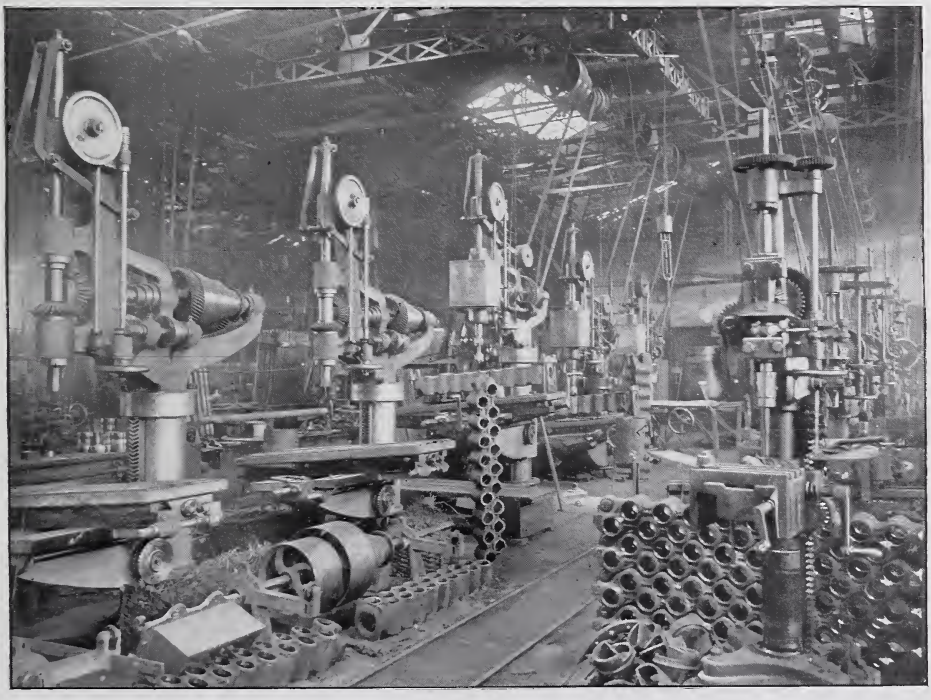


THE MODERN BOILER SHOP

By Joseph Horner

DURING the past twenty years the boiler shop has undergone a change, the magnitude of which is paralleled only by that in the machine shop. But while the latter has been mainly brought about by the introduction of new and improved machine tools, the former is due chiefly to the development of a new material,—steel. But for this, the old methods which were applicable to wrought iron would probably have not been altered much even at the present time.

There are many points in common between the machine shop of to-day and that of twenty or thirty years ago, but there are scarcely any between he boiler shops of the two periods. Twenty or twenty-five years ago few firms were making steel boilers; to-day the construction of new iron boilers is becoming exceptional. With the new material nearly every machine used, nearly every shop method adopted, nearly every detail of the work has been altered or modified in a greater or less degree. Hand work, too, is practically extinguished in the most modern shops. Formerly there was a good deal of flanging, bending, hammering, chipping, welding, riveting, drifting, and tapping done by hand, as there is still in small establishments; but good boiler work is now almost entirely a matter for machine tools, and the importance of these, therefore, has grown to an immense ex-



BORING HOLES IN THE HEADERS OF NICLAUSSE BOILERS AT THE SHOPS OF MESSRS. I. AND A. NICLAUSSE, PARIS

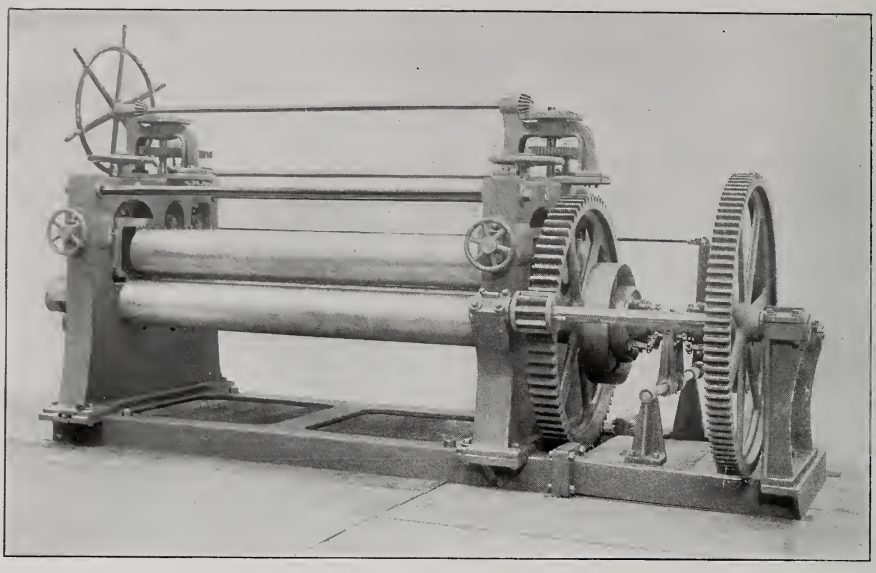


PLATE-BENDING ROLLS BUILT BY THE HILLES & JONES CO., WILMINGTON, DEL., U. S. A.

tent. A high-class modern boiler is now machine-made almost entirely from beginning to finish. Since the errors of hand work are thus eliminated, two boilers made to the same standard are exactly alike, and afford a striking illustration of the excellence of the machine work now done in the boiler shop.

Boiler making, to be carried on according to the best modern methods, requires a very large plant, so large that many a well-sized shop cannot afford it all. With only a moderate a nount of machinery good work can be done, but it has to be done in a more roundabout way, with considerable increase in cost, which, as in other departments, sorely handicaps such firms in competition with the big shops. Such being the case, our study must be chiefly one of the machines, in which the chief interest of the boiler shop centres.

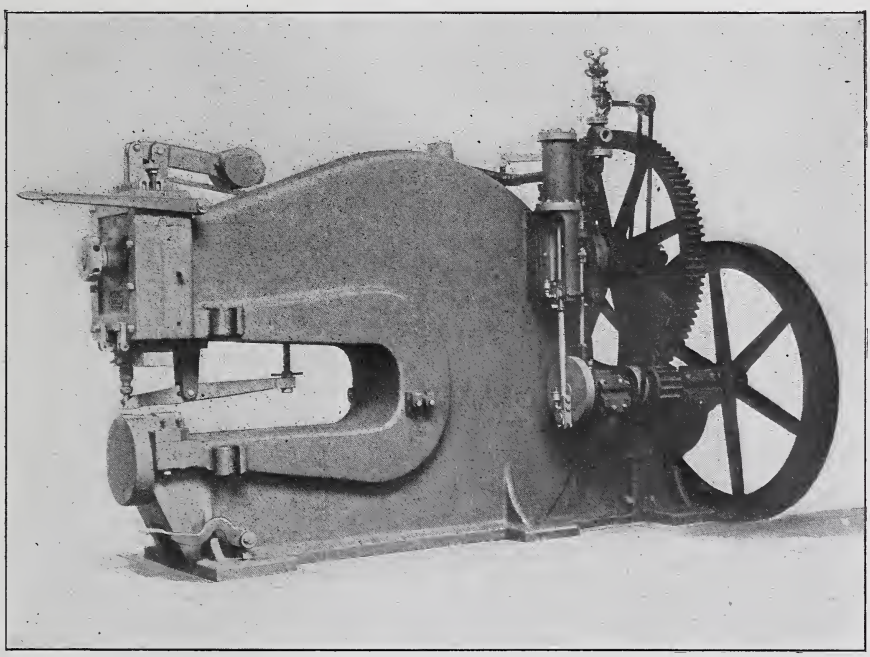
The principal operations carried on in the construction of boilers are the following:—Templating, shearing, flattening, planing, sawing and other cutting operations, bending, flanging, welding, punching, drilling, riveting, calking, tapping, and tubing. The first preparatory work done on most plates is to flatten them in readiness for marking off and tooling. There are three ways of doing this,—in flattening rolls, in common three-roll machines, and by hand. The first-named machine is rather too expensive a luxury for all boiler shops to indulge in, but it is a great time-saver, levelling a plate quickly and quietly. There are usually seven rolls in these machines, three above and four below, and the plate is passed through them in a slightly wavy or corrugated fashion, taking out the worst of the buckle. When the work is done in the common plate-bending rolls, the plate is passed to and fro between the top and bottom rolls several times, imparting a very slight curvature to it in alternate directions. This removes the worst of the buckles, but leaves a little correction to be done by the hammer. Plates of moderate size and thickness are easily straightened by a good plater by hammering them on a levelling block, though it is a rather tedious and very noisy method. The buckles are removed by hammering on the tight parts adjacent thereto. Angles are straightened by the sledge while supported in Vee blocks, on trestles; or squeezing machines are used for the purpose.

Flattening and straightening are preliminary to marking-out. The mark-

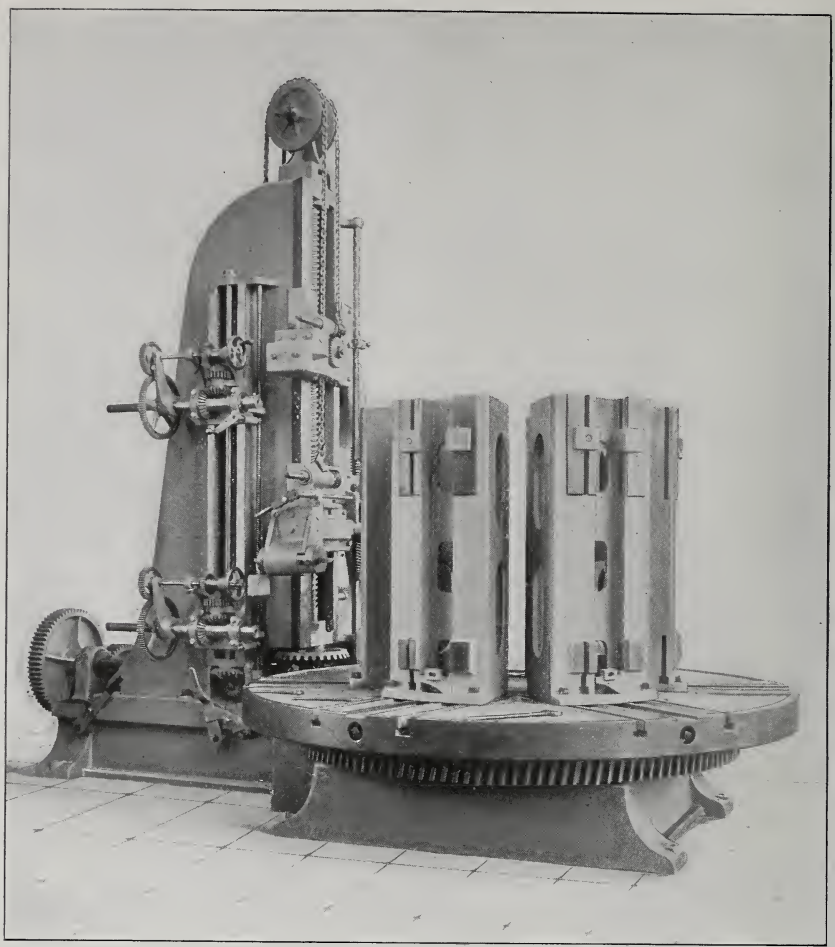
ing-out to dimensions, with the positions of centres and holes, is done by hand, or by templet. The value of the first is gradually diminishing, while that of the latter is increasing. Templating in large shops is the exclusive work of the templet makers, who, like the markers-out in machine shops, do nothing else. Both pine wood and sheet metal are employed. The first answers very well for strips, but is not so suitable for broad areas, even though strips are framed together at the corners. Sheet iron or steel is, therefore, used for nearly all permanent and standard work of large area, and the weight is lessened to permit of easy handling by cutting out lightening holes. Templating is indispensable when all work is standardised. Little more time need be occupied in marking a templet than in marking out a plate direct; the cost of material is a mere trifle, while the expense of shaping is immensely counterbalanced by advantages in point of economy of time and safety from error.

At this stage the plates and angles are passed on to the various machines, for the work of the old hands who were able to take a boiler and carry it right through with the assistance of their helpers is now divided among machinists, who plane, roll, drill, rivet, and much else, none of whom would be capable of taking charge of a complete boiler. And some of these will be specialists at one class of machine, but not at others, even though the work at each may be flanging or drilling.

The first work done on a prepared plate is to shape it. The methods adopted for shaping to finished dimensions in high-class shops may be summed up in one word,—cutting. Shearing, as a finishing operation, began to go out as steel came in. Edges are still sheared, in order to trim plates nearly down to dimensions, but final shapes must be cut by planing, or turning, or other equivalent operations. This is a rule to which no exception is permissible now, since the minute cracks left on



A DEEP-THROATED MACHINE FOR PUNCHING RIVET, FLUE, OR HAND HOLES. BUILT BY THE LONG & ALLSTATTER CO., HAMILTON, OHIO, U. S. A.



A CIRCULAR PLANING, SLOTTING AND DRILLING MACHINE FOR BOILER SHELLS. BUILT BY MESSRS. CAMPBELLS & HUNTER, LTD., LEEDS, ENGLAND.

edges of steel plates when left roughly sheared are liable to increase and become dangerous in working, and the rough edges, moreover, are not favourable to good calking.

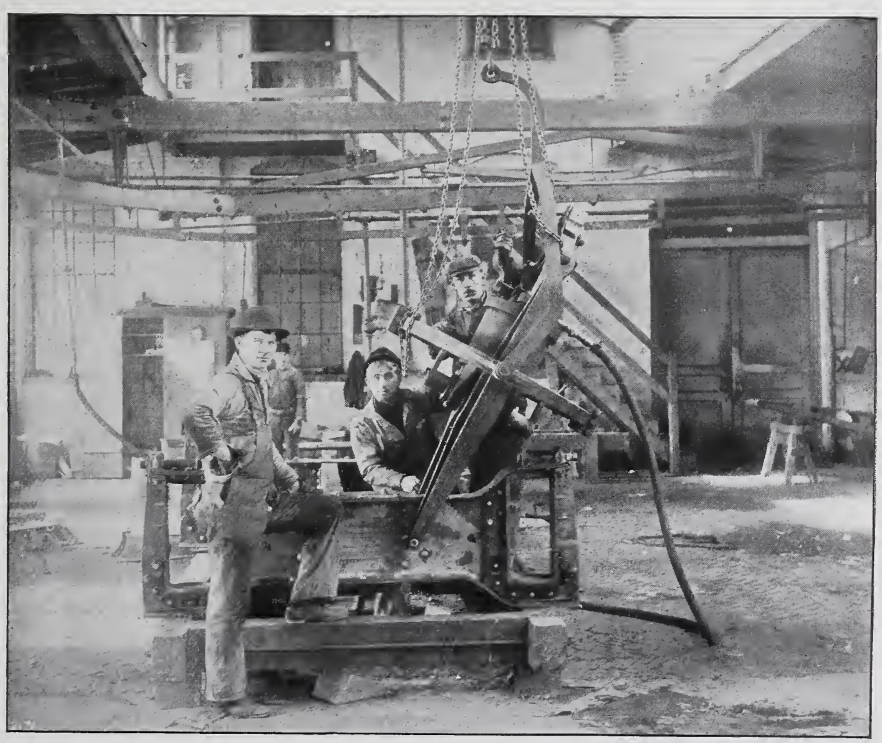
The number of edges which have to be cut by planing in boiler work much exceed those done by turning, comprising all those of the shell plates. With the enormous advance in the limiting dimensions of plates afforded by steel, the number of seams has been lessened. Many boilers, therefore, of a size once constructed with three sets of plates to the circle are now made with one only. Consequently plate-edge planers have grown in capacity until the most modern type is that which cuts two edges at once, so that one shifting of the plate only is necessary. Many of the largest machines plane up to 30 or 32 feet in length, by 10 feet in breadth, at one setting. Another time-saving design embodied in some machines is the use of hydraulic rams instead of screws, by which a plate can be clamped or released in a brief space of time. In some machines the transverse bed is made to swivel to an angle of 10 degrees on either side, which would be advantageous in planing bevelled ends on plates. One of the longitudinal tool slides also has a vertical adjustment, so that a strip can be cut from a plate. Tool carriages

in plate-planers either have a quick-return motion, cutting one way only, or there are two tool slides, to permit of cutting in each direction of the stroke.

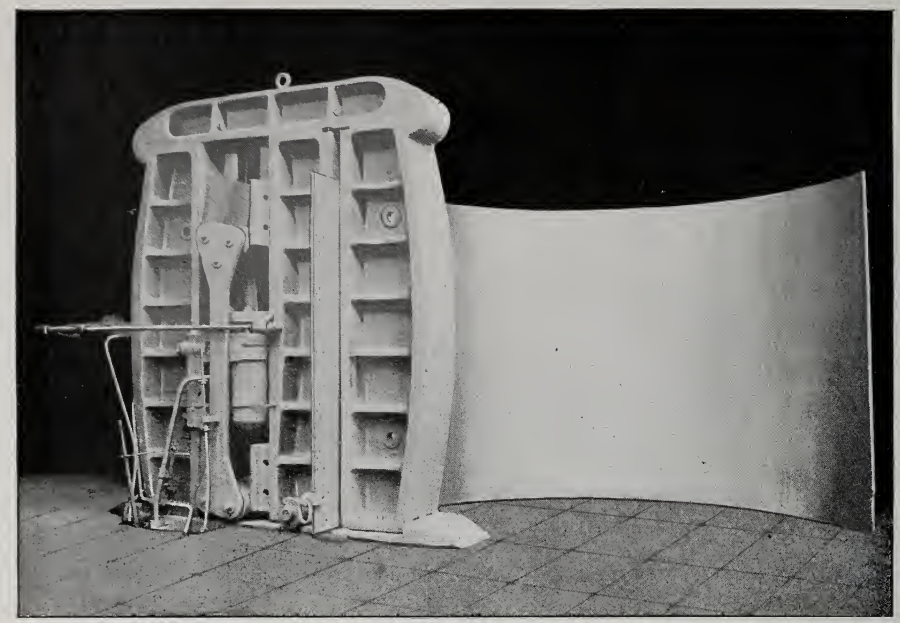
In standard practice the edges of boiler plates are planed before bending is done; but the machine shown on the page opposite planes the shell plates for cylindrical boilers after bending, the plates being attached to vertical blocks, adjustable for radius on a circular table, and planed on top and bottom edges, and slotted at the ends, at one setting. Tacking holes and rivet holes for mountings are also drilled in the same machine.

Thinning corners in those parts of joints where three plates cross was formerly invariably done by heating the corner in the fire and hammering it down. This did little harm to iron, but it proved injurious to steel, and hence corners are now, in the best practice, thinned by planing to a bevel. This does not spread the corner as hammering did, but that is a matter of no moment. The planing machines used have duplex heads, so that two corners are thinned simultaneously. In some cases corners have been milled.

Leaving, for a moment, the other cutting operations which are done on end plates, rings, etc., we will follow the shell plates a stage farther. Formerly the practice was universal of bending plates after the rivet holes were punched or drilled. This has not yet been entirely discarded. But in good practice to-day this is exceptional, for, quite outside of the desirability of drilling right through seams when tacked in place, it has been proved by experiments that steel will not stand bending after the drilling or punching of rivet holes to so great an angle as when unperforated. When a plate is perforated, the continuity of the metal in the line of holes is broken and its elasticity impaired, so that it will not extend so readily as a solid plate, and, therefore, will fracture



A UNIVERSAL PORTABLE RIVETER, MADE BY THE BETHLEHEM FOUNDRY & MACHINE CO., SOUTH BETHLEHEM, PA.



A HYDRAULIC BENDING MACHINE FOR BOILER PLATES, MADE BY MESSRS. FIELDING & PLATT, LTD., GLOUCESTER, ENGLAND. BENDING A 6-TON SHELL PLATE FOR A MARINE BOILER AT THE CENTRAL ENGINE WORKS, WEST HARTLEPOOL

sooner. This consideration alone would clearly demonstrate the desirability of bending boiler plates before drilling them. The shell plates of boilers are bent cold. Steel that would not stand such treatment would not be suitable for use. When plates are of great thickness, this means correspondingly heavy rolls. When the attempt is made to do heavy work with rolls too light for the purpose there is a temptation to heat the plate to redness in order to facilitate the bending. There is risk in doing this, because the chances are that the plates will have reached a blue heat before the bending is completed,—the most dangerous heat at which work can be done upon steel.

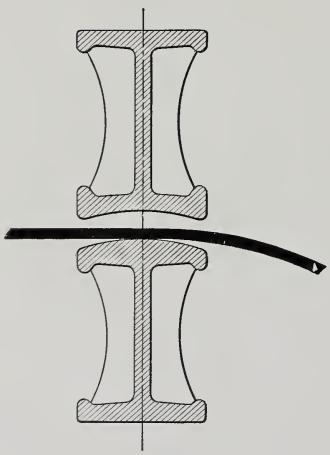
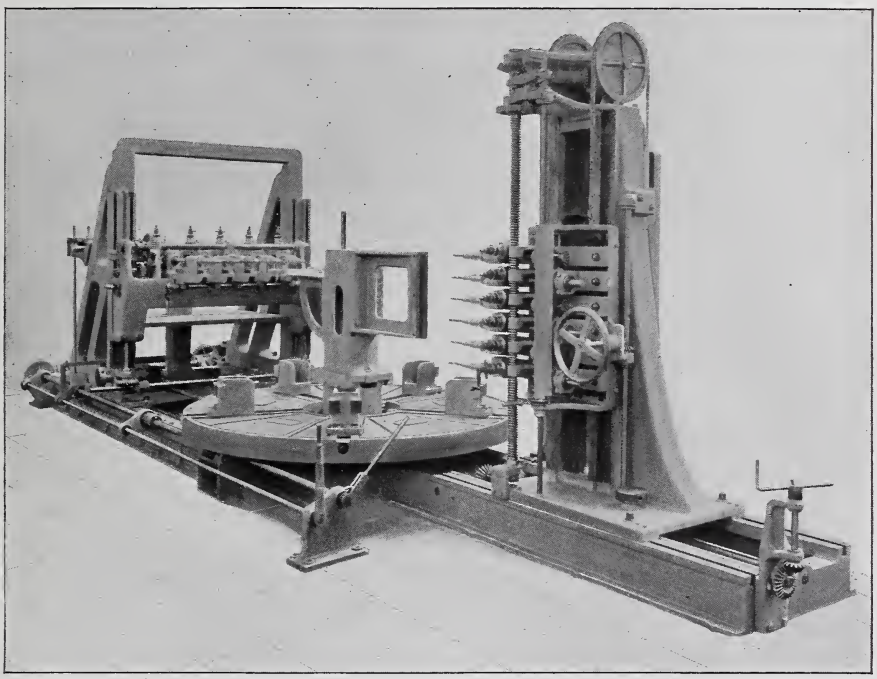


DIAGRAM SHOWING ACTION OF HYDRAULIC BENDER

The bending rolls suitable for the plates for, say, Lancashire and locomotive boilers, are unsuitable for those of the heavier marine boilers. Bending rolls for the latter are generally of the vertical type, which lessens the difficulty of manipulation of the massive plates employed. Each type is driven by its own engine, the machine being self-contained. The electric motor also has been fitted to such rolls, and its use will, doubtless, extend rapidly. These self-contained arrangements have been rendered more necessary with the increasing massiveness of these machines and their wider separation in the shops, which renders transmission of power by

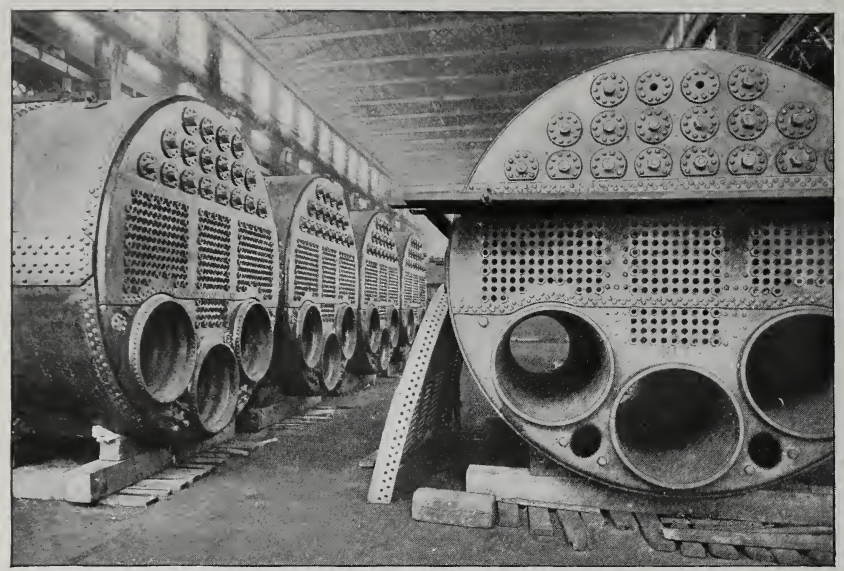
lines of shafting undesirable. One drawback to the action of the common bending rolls is that the curving action does not extend to the extreme ends of the plate. The ends of a plate, therefore, are curved first, either by pressing them between dies,—which is the proper course to adopt,—or by the hammer, which is poor practice. Machines are made with four rolls, instead of three, by which a circle can be bent right to the ends. A special type of bending machine, shown on the opposite page, completes the curve to the end. The special characteristic of this machine is that instead of rolls, vertical dies are used. One outer fixed girder has its inner face convex. The centre movable girder has its opposed face concave, and between these the plate is squeezed in successive lengths, as explained by the diagram. The movable girder is forced against the plate by a vertical ram, which slides against inclined planes on the fixed girder adjacent. The plate is moved around by automatic feed gear, and the largest and thickest plates can be bent in about twenty minutes.

The bending of rings of angle sections for boiler shells and furnace tubes is done in many cases by casting a block of the required radius, and setting the angle iron round it. This has been abandoned in modern shops in favour of a machine like the bending rolls in principle, in which two rolls are fixed, and one is adjustable. The operating gearing is beneath the floor, and the angle lies on a cast iron plate level with the floor. The angles are bent hot. Butt straps are bent to their curve between convex and concave blocks in a hydraulic "butt and joint strip bender," or by hand, in a die block.



A BOILER SHELL DRILLING MACHINE BUILT BY MESSRS. CAMPBELLS & HUNTER, LTD., LEEDS

In following the work through the boiler shop, we must defer the consideration of the methods of drilling and riveting to their proper place and in the meantime consider the various details which have to be prepared for the final work of union. We return, there-



SOME OF THE BOILERS OF THE WHITE STAR LINE STEAMSHIP "OCEANIC"

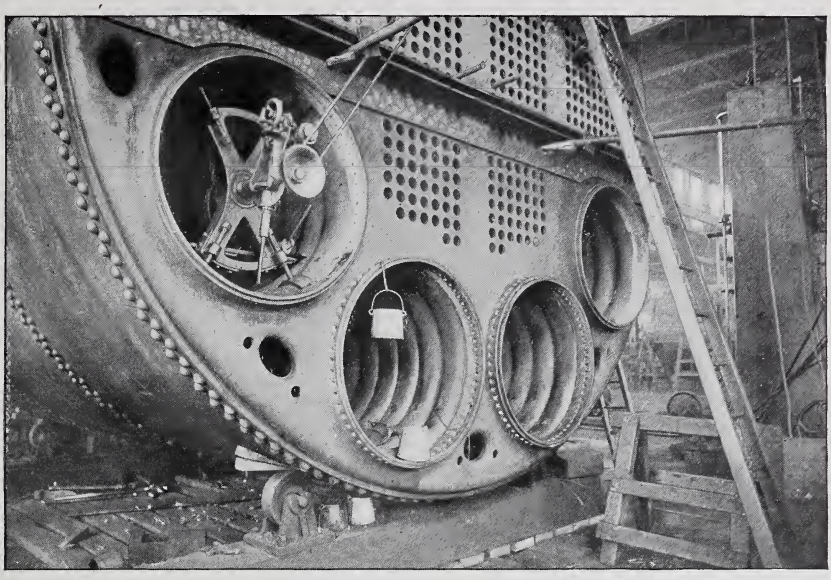
fore, first to the work of cutting edges, such as the calking edges of end plates and angle rings, the holes for furnace mouths, for man-holes, and mud holes, those for some of the mountings, and small holes for tubes.

Man-hole punching machines are not used so much for boiler as for bridge and girder work. The proper machine is one fitted with adjustable elliptical motion for the cutter head, so that a considerable range in size of cut can be covered. But in modern tools the functions of cutting round and oval holes, and of turning the end plates of boilers and the edges of calking and angle iron rings are combined in one, as in that illustrated on page 46, which performs all the above-named operations on a plate at one setting. The calking edges of angle rings by which the front plates of Cornish and Lancashire boilers are secured to their shells are also turned on horizontal revolving tables.

The holes in the tube plates of marine boilers are bored by machines which, in some designs, have three spindles, operating simultaneously, each being adjustable on the cross slide for pitch, and having self-acting feeds. A steel centre runs through each spindle to nip the plates, and the holes are bored with cutters arranged in boxes. The table that carries the plates is traversed underneath on a planing machine type of bed, which is fitted with dividing motion for pitching out longitudinally. Small holes for the tubes of locomotive boilers are best drilled through a thick metal templet, embracing all the holes in a tube plate.

In the absence of the special boring and turning machine just named, circular holes for furnace mouths can be bored in an ordinary face lathe, just as the calking edges of flanged crowns are commonly done, and small round holes may be bored under a drilling machine, though, of course, with some loss of time in setting the work. But oval holes must be cut by hand; and many are still done in this way, to which there is no objection except that it is a rather roundabout and expensive process. To cut them by hand, a number of small holes are punched adjacent to the edge of the main hole and touching one another, so removing the central body of metal, and then the edges are chipped to the line with a cold chisel.

Angles and tees for gussets are cut to



DRILLING RIVET HOLES IN THE FURNACE MOUTHS OF ONE OF THE BOILERS

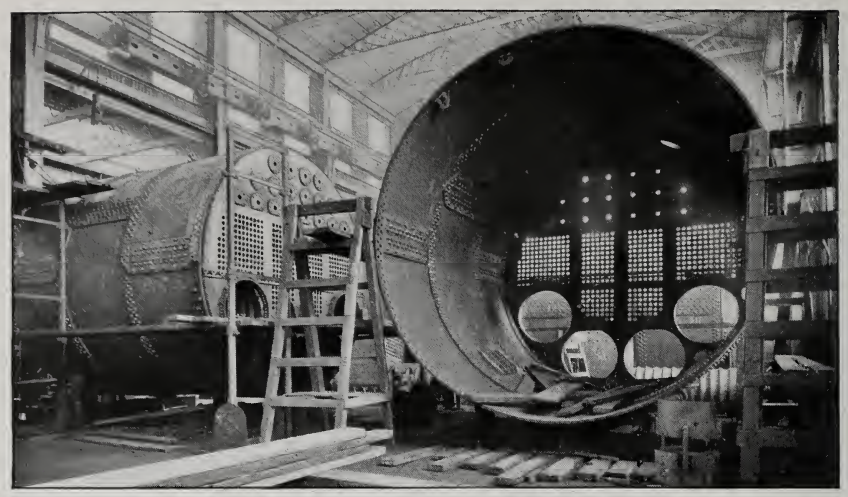
neat lengths by the cold iron saw, which leaves smooth ends, as though planed, being, in this respect, superior to the hot iron saw, which leaves a rough surface.

Take, next, the important work of flanging. Some of this is done on every boiler. There are the crowns of the fire-boxes and shells, and the cross tubes, of the vertical type; the back plates of Cornish and Lancashire boilers, the Adamson seams of the furnace tubes, the flanges of the conical tubes, the man-hole seatings, the front and back plates of marine boilers, and plates of combustion chambers, while the locomotive boiler beyond the barrel is nearly all flanging and bending. In crowns and end plates there is much hand flanging done still, because heavy work requires a massive hydraulic press and blocks.

A great deal of interest might be written about flanging operations and the appliances employed, for its importance now is greater than ever it was, and a most marked difference between the methods of the modern shop and those of only a few years since is the displacement of angle rings by flanged plates. The angle ring was once an extremely convenient and nearly indispensable means of attachment, and two rings were sometimes united to form a double flange. To this there was no alternative save hand flanging, —a process, in such cases, of slow and awkward detail, with uncertain results.

The expense, the lack of neat finish, and want of perfect shape are not always the worst evils associated with hand flanging, for, outside of these, is the probable reduction in thickness of metal, and the injury done to steel and inferior iron by successive heating and hammering at cooling temperatures. Good hand work, therefore, has always been a specialty of a limited number of men, —angle iron smiths chiefly,—who command good wages and piece-work prices.

Another fact which has contributed to the lessening importance of the angle iron ring is that steel stands flanging very much better than iron, by reason of its higher ductility. Hence, we often have the shell crowns of vertical boilers flanged to embrace the uptake, and the front plates of marine boilers to receive the furnaces. In some places the plates of Cornish boilers are flanged similarly.



THE SHELL OF ONE OF THE "OCEANIC'S" BOILERS

Dome crowns also, and the end plates of Cornish and Lancashire boilers are so treated, and weldless rings are made by stamping between top and bottom die blocks, while other examples will occur to the mind of flanging in steel having displaced the angle iron ring.

Machinery for flanging is subjected to much variation. It may, however, be broadly divided into three classes,—those which turn an entire plate at one heat; those that bend a flange piecemeal, but still by direct pressure operating in the plane of the flange; and those which do their work by a gradual rolling action. For the first two, cast blocks are required; for the third, no rig-up is necessary beyond the mechanism of the machine. The first two are operated by water rams; the third is belt-driven. The hydraulic flanging press has attained a position to-day without a rival, being indispensable in all the great boiler shops. The actual flanging of a tube plate, or smoke-box plate, is done within two minutes. But the heating and the setting of the plates, the capital outlay, and the cost of blocks are the real measure of expenditure, which is recouped only by a large volume of similar work, and by doing it in sets at one heating of the furnace.

In the common hydraulic flanges the work is held by one set of rams, while the pressure for flanging comes through another ram, or set of rams. Machines of this class are made to flange plates up to 1¼″ or 1⅜″ in thickness, and they will weigh from about 20 to 100 tons. Among the largest of this kind are two of the Tweddell type at the Crewe and one at the Swindon Locomotive Works, which are capable of exerting a total pressure of about 650 tons on a plate. These machines weigh over 100 tons each.

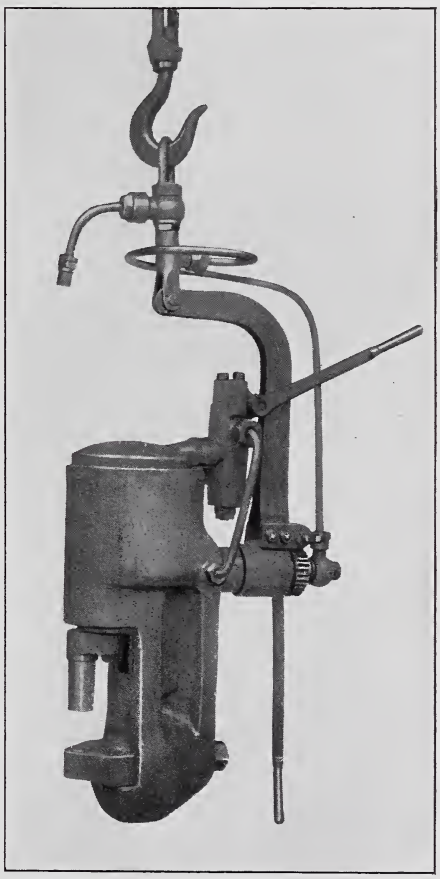
Broad rectangular presses of this kind are used in the flanging of tube and throat plates and fire-box and smoke-box plates of the locomotive and the agricultural type of boilers, and for the shell and furnace crowns of vertical boilers, and other work of that class. But the end plates of marine boilers, by reason of their more massive dimensions, have been flanged by hand in short heats and short sections in the same way that all flanging, whether light or heavy, was done a quarter of a century ago. But a machine which, in its method of operation, imitates hand flanging, is now used in a good many heavy marine boiler shops. The plate to be treated, as shown in the illustration on page 48, is gripped down on a bending block by means of a vertical ram. Another ram descends on the edge of the plate, turning down a portion to form

a length of about 12 inches of flange, the operation being repeated on several successive lengths until 8 or 9 feet are done. Then the flanging ram is removed, and a horizontal one comes into play, imparting a neat square finish to the flange. Though the operation is slow by comparison with the flanging of a locomotive plate at a single heat, it effects not only an important saving of time over hand flanging on thick plates, —for which, when of large diameter, top and bottom dies are out of the question,—but the work is done more uniformly, with less stress to the material. Furnace mouths in end plates are also flanged on the same machine subsequently at one heat by means of circular dies, in which case the two vertical rams are coupled to exercise their united power. The machine can also be adapted for flanging flue rings and shell plates.

The general adoption of the Adamson flanged seam rendered the tube-flanging machine necessary, by which the hand labour of several hours, with several heats, is reduced to about a minute, with a perfect flange made at one heat. The end of the tube is heated in a vertical or a horizontal furnace, is gripped in the chuck of the machine with the heated end uppermost, and rotated rapidly, while the roller turns over the flange in less time than it takes to read this paragraph. Few large shops are without this useful machine, while those who do not possess it send their flanging to be done by it.

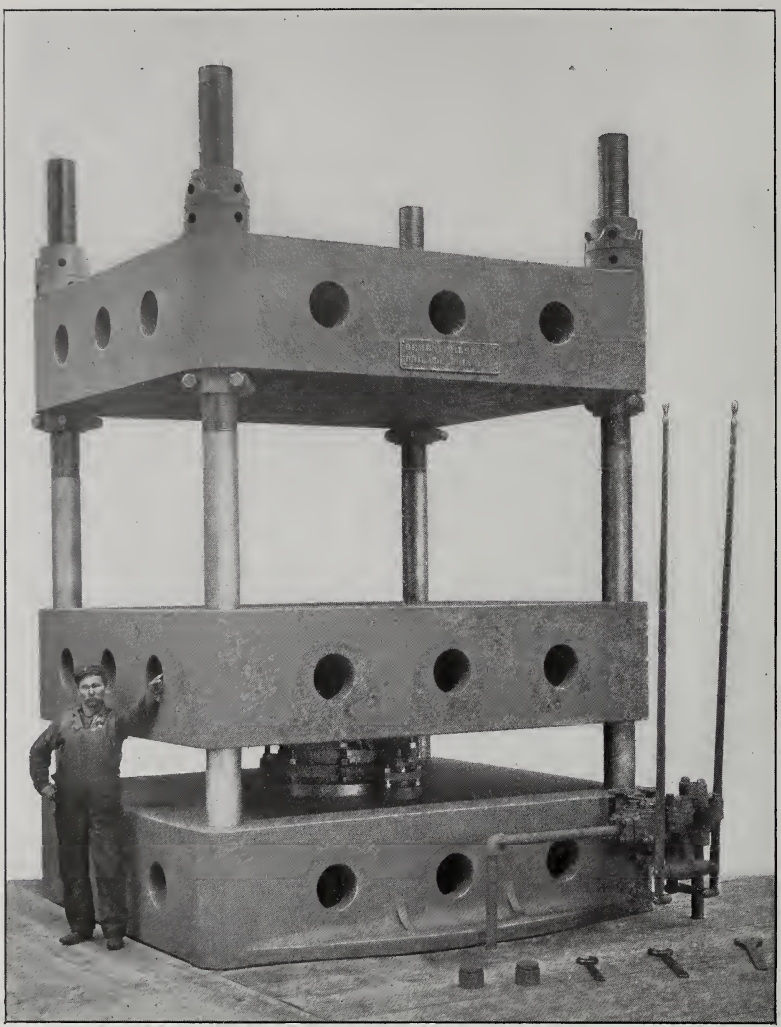
It is not easy for the younger generation to realise the immense value of the invention of the Adamson seam. Fairbairn's famous rule for the collapsing strength of long tubes was, with its various amended forms, for many years a stumbling-block to boiler makers. The very low collapsing strength of long, plain tubes rendered their reinforcement necessary by encircling rings of angle, tee, or flat sections, which formed nuclei for deposits. The Adamson seam came as a complete solution of the difficulty. By it the flue is divided into a number of short tubes, and so flues which, if unsupported, would not stand more than 20 or 30 pounds pressure, are rendered capable of sustaining five or six times that amount with safety.

The name of the late Daniel Adamson is inseparably associated with the development of the steel boiler. "Dan Adamson," as he was colloquially termed by admiring Manchester men, made steel boilers when nearly every one else distrusted the new material.



A PORTABLE HYDRAULIC RIVETER FOR MARINE BOILER FURNACE MOUTHS FLANGED OUTWARDS. MADE BY MESSRS. FIELDING & PLATT, LTD.

He experimented with steel in every conceivable way, even exploding gun-cotton on plates with a view to imitate the effects of a boiler explosion. After having made 3000 steel boilers, he said



A HYDRAULIC FLANGING PRESS BUILT BY MESSRS. BEMENT, MILES & CO., PHILADELPHIA, PA., U. S. A.

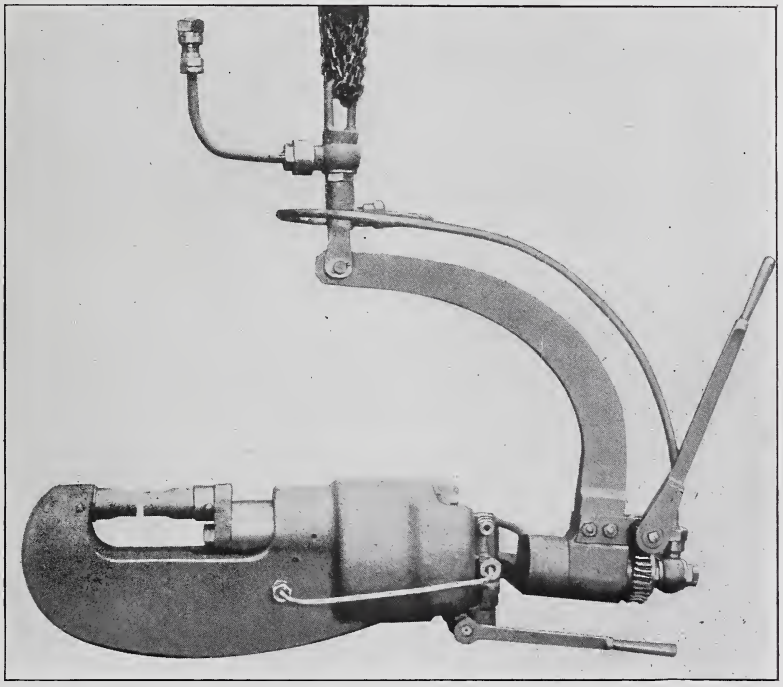
there had not been one accident in their subsequent working at pressures from 50 pounds to 250 pounds per square inch.

There are good reasons relating to the working of steel, quite apart from economies of time, why hand flanging is not so satisfactory as that of the machine which turns a flange at one squeeze, or by a swift circular rolling movement. A good deal of this work is, nevertheless, done by hand, in which case it is desirable to anneal it afterwards. This is not absolutely essential in all cases, and all boiler work is not treated thus; but it is safer.

Bending blocks of numerous forms are required in a shop. Besides those used on the flanging machines, there are others, employed for hand flanging and for bending angles to regular curves. These are either of simple types, or fitted with a lever and rollers for turning over and setting the work. The flanges of cross tubes in many shops are set against blocks. Suitable blocks

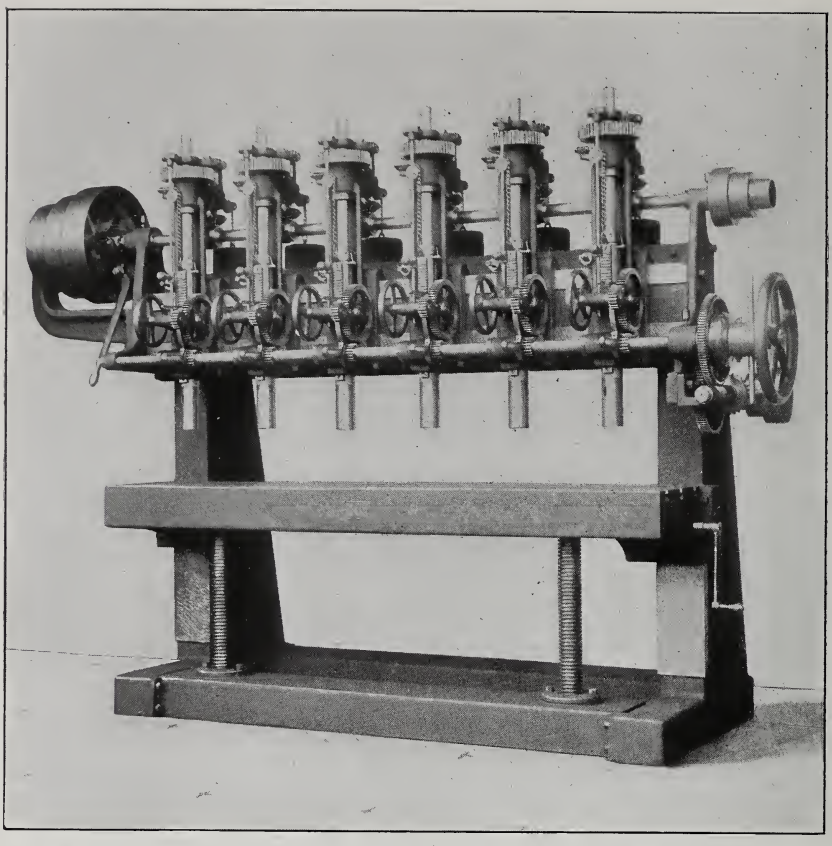
also are used on the tables of the cold iron saws to carry angles and tees while being cut off, and blocks are laid upon trestles to hold the angles and tees while being straightened or marked off. In every shop, too, there are blocks designed and rigged up to meet the requirements of a special class of work, with the result of reducing labour cost, while, at the same time, a higher degree of accuracy is secured. These blocks are mostly made of cast iron, and are stiff, cheap, and readily removed.

In the furnaces for Lancashire and Cornish boilers, and in cone tubes, welding precedes flanging. The plates, being of smaller diameter relatively to thickness than shell plates, are bent while red hot,—the furnaces in the common rolls, and cone tubes over a mandrel. The furnaces of vertical boilers are, as a rule, riveted, though many instances occur of welded joints,—a practice, however, which has nothing to commend it. Furnaces of horizontal boilers,—now welded,—were riveted in the older practice, but the double thickness of seam was more objectionable in these than it is in vertical boilers. Cross tubes and uptakes are made by welding in good iron, or in low carbon steel. The welding of tubes is often done by hand in short lengths, though in large shops a power hammer is generally employed, the seam being supported on a mandrel. The tubes are also frequently flanged by hand, but there is also a flanging machine having an arrangement for holding the tube against a revolving face plate with rollers which turn over a flange at one heat.



PORTABLE HYDRAULIC RIVETER, DOUBLY HINGED, FOR CLOSING RIVETS AROUND FIRE DOOR AND FOUNDATION RINGS OF LOCOMOTIVE BOILERS. MADE BY MESSRS. FIELDING & PLATT. LTD., GLOUCESTER, ENGLAND

The safety of a boiler is very much a question of riveting, and the modern ways of a shop may be very nearly estimated by an inspection of its riveting plant. By the old methods rivet holes were punched in plates before bending; now they are more often drilled after



A SIX-SPINDLE DRILLING MACHINE BUILT BY THE BICKFORD DRILL & TOOL COMPANY, CINCINNATI, OHIO, U. S. A.

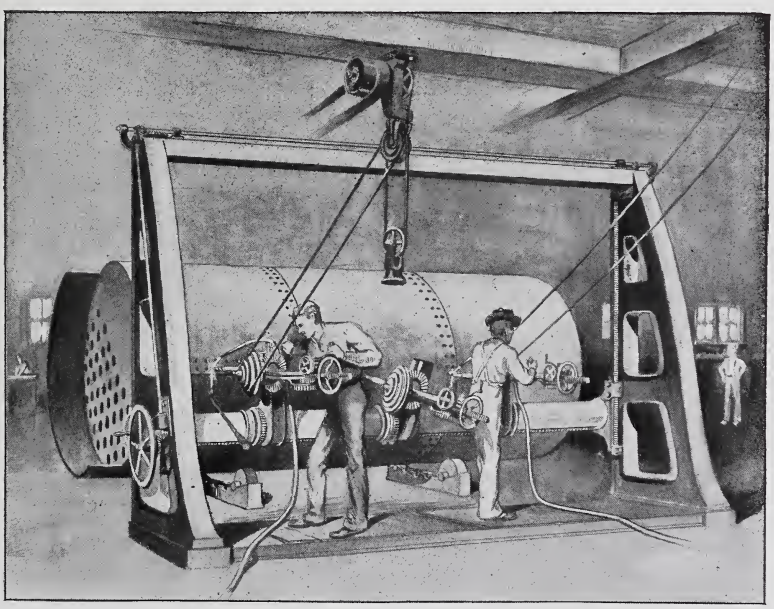
bending. Formerly the holes in the plates were punched independently of those in the plates or rings adjacent, and their mutual accuracy depended on the marker-out, or on the templets used, and so the abuse of the drift crept in. Now the plates are drilled through, with the seams in place.

Many experiments have proved that holes punched and reamed left the plate as sound as though holes were drilled in the solid, because the reaming removed the minute cracks produced by the punch, which extended only about one-sixteenth-inch inwards. But this method is open to two objections. One is that holes can be punched only through one plate at a time, and there is the probability of some overlapping of the punched holes, with the result that the reamer will take all the metal from one side only, leaving cracks on the side opposite. A later and better practice is to drill shell plates before bending,—the holes being drilled from a templet in batches of three, four, or five at a time,—these, of course, representing similar plates for as many different boilers. But as experiments have shown that when the continuity of fibre is broken by the presence of holes the plate does not bend so well as when it is solid, it is better to drill rivet holes right through the lapping plates, or through butt straps and plates after bending,—a practice which is now very general in the best modern shops, and is enforced in specifications. Hence has arisen the occasion for the development of the various boiler drilling machines. The objection to drilling, on the ground of its expense, no longer

holds good, for it is as cheap as punching. The expense of machinery is heavy, but so is that of a boiler explosion.

Boiler drilling machines have gone through many variations and improvements, mainly in the direction of multiplication of spindles, in their automatic regulation, in dividing movements for pitching the holes, besides numerous minor details. The broad difference between the early and the later boiler drilling machines is, that the former drilled the rivet holes before the plates were put together, while the latter drill them afterwards. Both types use multiple spindles; but the earlier were vertical spindle machines, while the later ones have horizontal spindles.

No single drilling machine will cover the whole range of boiler work, but for the various types of boilers and different parts of a single boiler different kinds of machines are employed. The most complete machine for the Lancashire boiler has a row of horizontal spindles carried on one column for the circular seams, and a row of vertical spindles carried on another column for the longitudinal seams. Such a machine is costly, and one with half a dozen spindles arranged on two columns will satisfy the requirements of many shops. Some machines for Lancashire and locomotive boilers have one standard only. Those for marine boilers have several standards placed at an angle, each carrying a single saddle and spindle. In the first-named types the boiler shell stands in a vertical position on the chuck, or table. In the marine type the shell is carried in a horizontal position on rollers which are rotated by power gear. In every case the spindles are capable of adjustments to point to the centres of boilers of different diameters, and their heads are counterbalanced. Furnaces are drilled in machines with vertical spindles, or in a horizontal machine with two drilling heads which operate on both ends at once, the heads being so made that the drills will act either parallel for drilling flanges, or at right angles for holes to receive the end angles. Finally, there are many portable drills, held in the

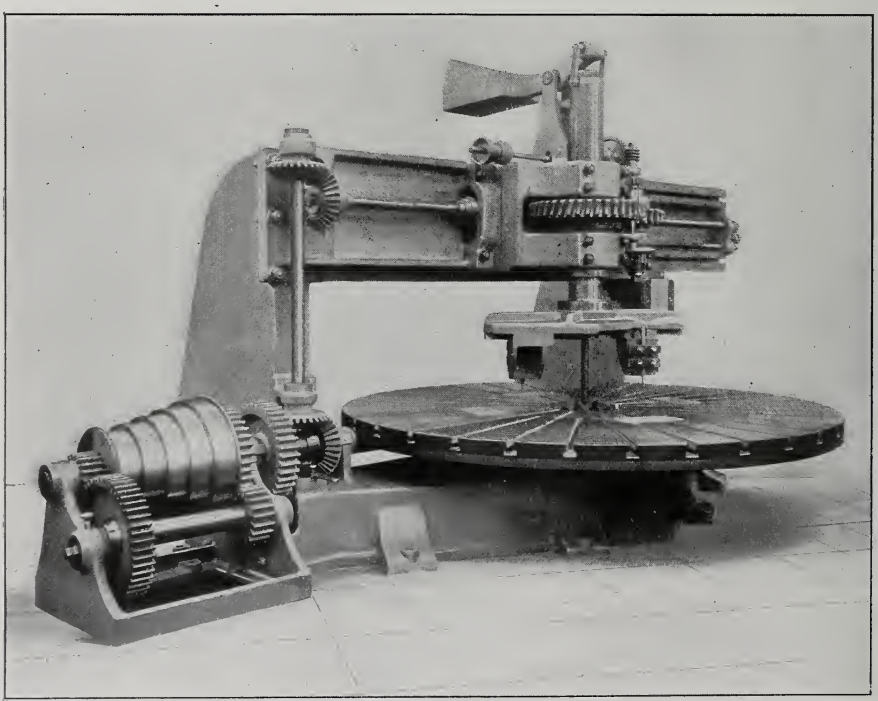


A BOILER SHELL DRILLING MACHINE BUILT BY MESSRS. PRENTICE BROS., WORCESTER, MASS., U. S. A.

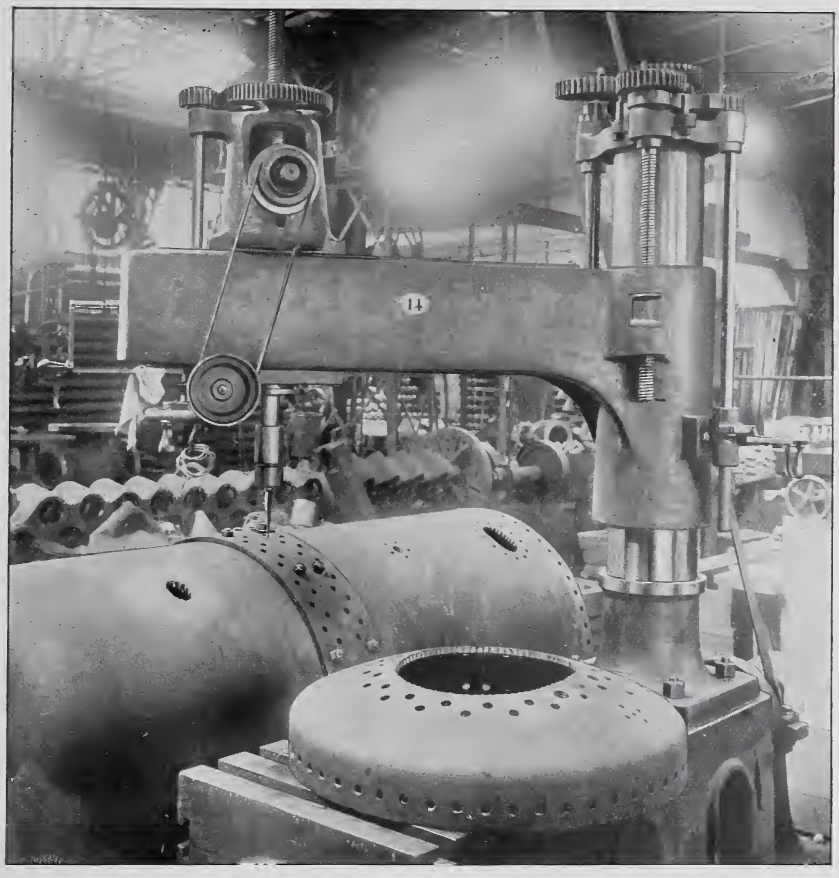
hand, for drilling small holes, in place of hand drilling. These are actuated by cords from overhead, by compressed air, or electricity, or by flexible shafts.

It seems unnecessary now when machine riveting has signally triumphed to say much about the advantages which it possesses over hand work. Still, these results may be noticed, that the economy is not entirely due to the saving of wages,—though this is very great,—but also to better results. Tighter seams are made, and there is, therefore, less trouble with leaks to be made good by calking, and less risk of trouble in subsequent working. A rivet which is squeezed fills its hole more closely along its whole length than one of which the tail end only is turned over by hammering, the effect of which is but local. In fact, with the thick steel plates and large rivets used in the high-pressure marine boilers of the present decade good results would have been impossible by hand riveting. And another important advantage lies in the plate-closing device, which, in heavy work, squeezes the plates into absolute contact before the rivet is closed.

As with drilling machines, so with riveting. No boiler can be riveted throughout with a single machine, or single type of machine. For work on shells, the fixed type is used; but for nearly all other classes portable machines are employed, and of these there are several types. A few years ago some sections of locomotive riveting were beyond the then attainable range of machine riveting. Now the portable machines work around fire holes and foundation rings, and can be moved to various angles to follow the rows of rivets. We have advanced a long way from Fairbairn's riveter,—the "Iron Man,"—thanks to the late Mr. Tweddell, who did more for boiler shop tools than any other individual, and who, starting from simple machines, produced constantly improved types as the wants



A MACHINE FOR CUTTING ROUND AND OVAL HOLES AND TURNING THE EDGES OF END PLATES AND ANGLE RINGS FOR LANCASHIRE BOILERS. MADE BY MESSRS. CAMPBELLS & HUNTER, LTD., LEEDS.



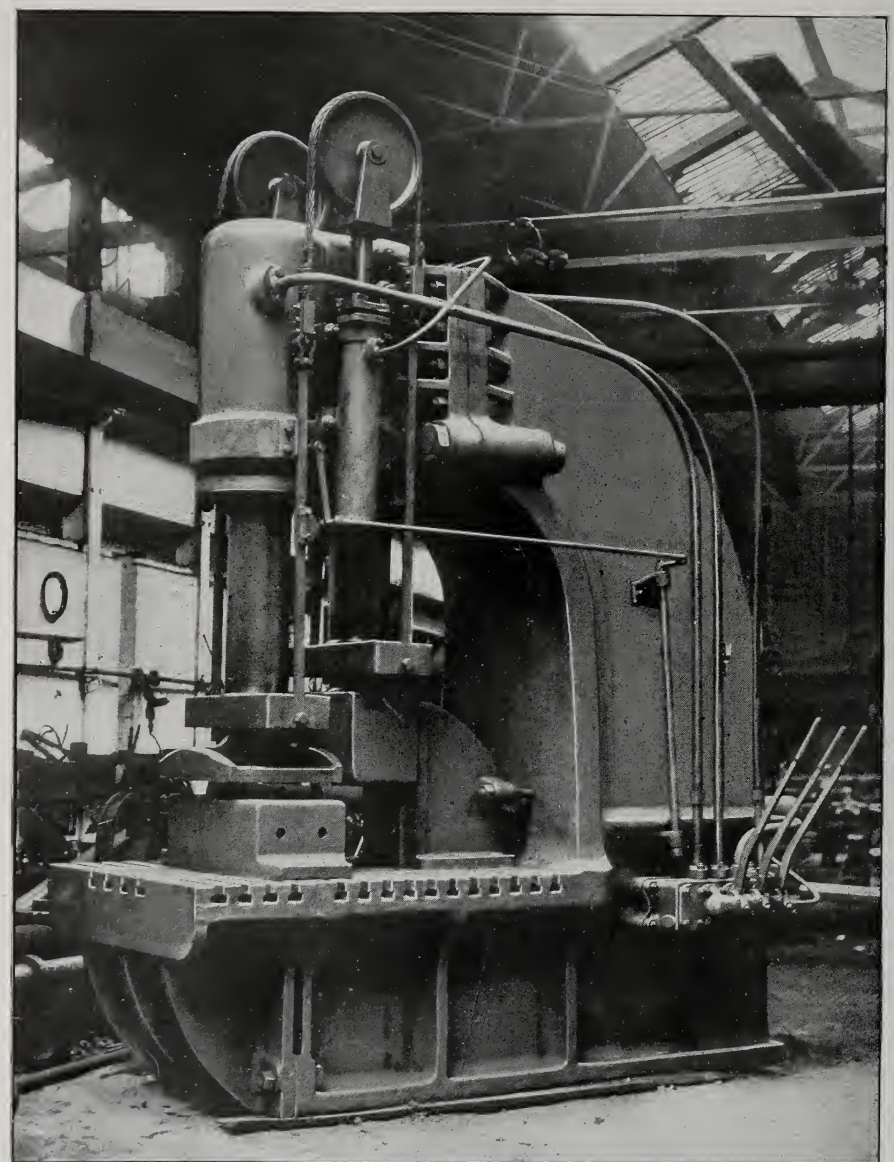
DRILLING CIRCULAR SEAMS IN THE DRUMS OF BOILERS AT THE SHOPS OF MESSRS. NICLAUSSE, AT PARIS.

of the boiler makers became more exacting.

The shells and furnace flues of Lancashire and Cornish boilers are, in consequence of their great length, riveted under a tower. This "riveting tower," formerly built of timber, is now built solely of brick, and is fitted with suitable hoists to suspend and manipulate the shells and flues over the fixed riveters beneath.

Calking may appear a small detail; yet it has been a source of much trouble and danger. It has been often badly done with a thin tool against roughly sheared edges, the result being that the edges were merely burred, and an incipient groove was cut in the surface of the plate adjacent where grooving ultimately developed. Such a barbarous practice would not be tolerated in any decent shop to-day. The proper course is to plane or turn the calking edges to an angle of about 1 in 8 before being riveted, and to calk, or, rather, fuller, them with a broad-faced tool,—treatment which inflicts no injury, and is less likely to open the edges of the plates than a thin calking tool would be.

Calking by the hand hammer predominates in most shops to-day. When performed by a careful man, there is no objection to it. But the method is more costly than power calking, done by pneumatic tools. The objection to the latter is the deafening noise and the jar to the hands. The pneumatic hammer is a wonderful tool, and though one



A HYDRAULIC FLANGING PRESS BUILT BY MESSRS. FIELDING & PLATT, LTD., GLOUCESTER, ENGLAND

cannot take very kindly to it, it is an essential in the modern shop, and has come to stay.

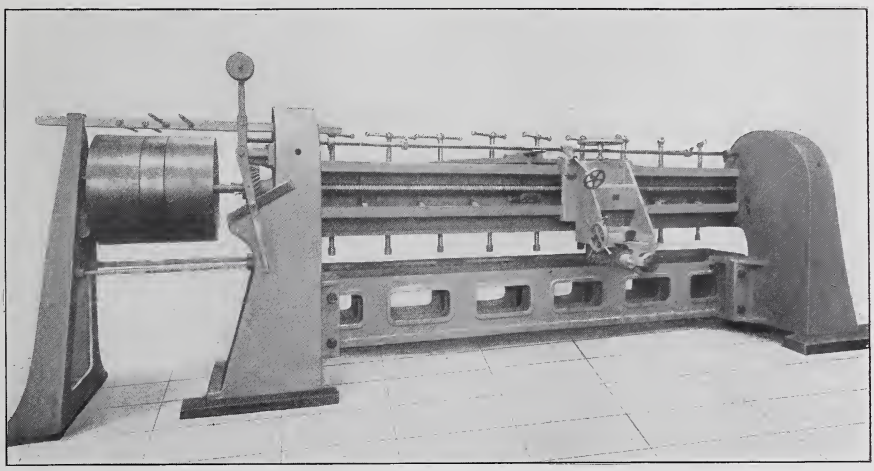
Rollers are used to support large circular shells while calking is being done The rollers are of cast iron, carried in cast, or in plated frames, and several sets of these are required in a shop. The boiler shells are easily rotated on them to bring seams to be worked on uppermost, affording facilities for other work besides calking.

Since it is clear from the foregoing observation that many of the large machines which are employed in the boiler shop for identical operations, such as bending, flanging, drilling, and riveting, can have little in common but the name,

and as the use of machinery has displaced hand work, it follows that boiler making has become more and more specialised, and firms find it to their advantage to restrict their operations to one or two closely related types only. Obviously there are great differences between the marine and Lancashire boiler shops, between the locomotive and the water-tube, and the vertical boiler shops and their machines and methods.

Beyond the economies effected by a highly specialised machine tool there is, too, that obtained by working on stock boilers in sets. This is readily done in those shops where a special type is got ready. There is no portion of a standard boiler that cannot be put into stock in a greater or less advanced stage. It would not have been safe to do so under the old system, when most parts had to be fitted to others. In turning out work in this fashion the labour costs on a single piece are insignificant.

The general arrangements of the boiler shop, like those of other departments, should, as far as possible, be such that heavy work does not traverse the same ground twice. The stores for plates and angles should be at one end, or side, nearest the heaviest machines and large furnaces. Trolley tracks, say, of 2-foot gauge, should run down the

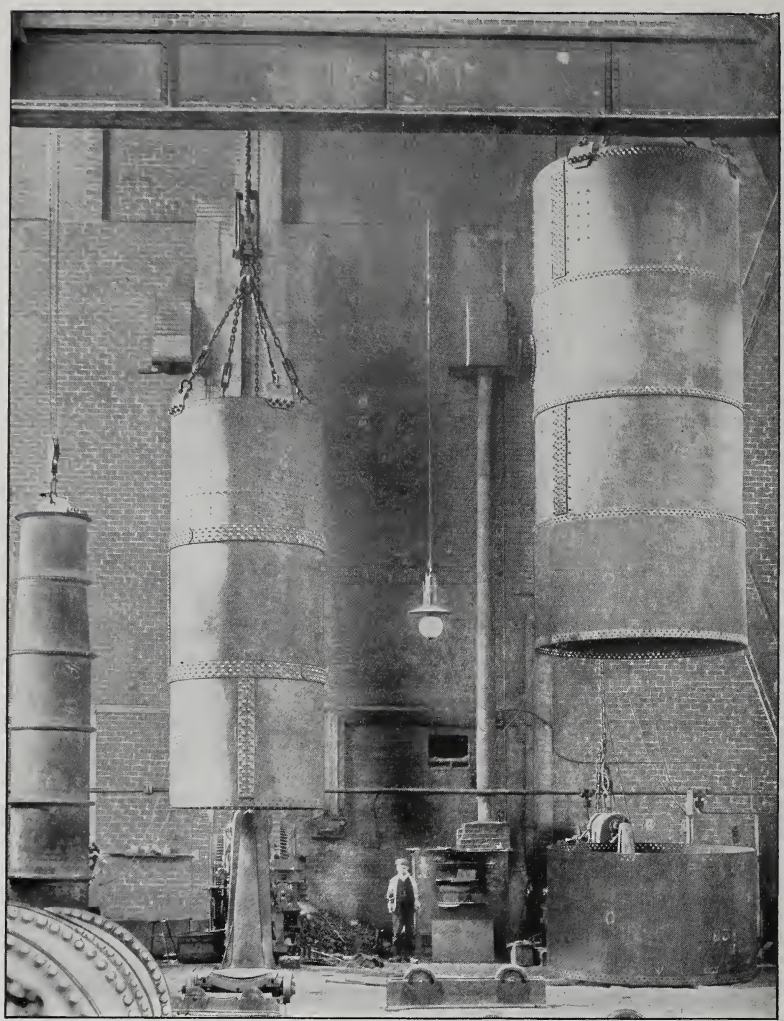


A PLATE-EDGE PLANING MACHINE, BUILT BY GEORGE ADDY, SHEFFIELD, ENGLAND

made in standard sizes to unvarying proportions; where for a certain diameter there is a given length, or height, a given diameter of furnace, and fittings to suit. In this respect the large shop is at a great advantage by comparison with the smaller one.

Though stock of this kind is bulky, and requires considerable storage room, the separate boiler parts can be prepared and stored when space is limited. Plates can be planed, and bent, and drilled, but need not be riveted; furnace tubes can be flanged; end plates flanged and tooled; cone tubes finished; gussets cut and angles riveted to them; stays turned and threaded; and all the small fittings shop and serve the larger machines. So much material and so many bending and flanging blocks of large size are brought into a shop, and so much finished work is taken out, that several large doorways are necessary; in fact, some shops are little better than open sheds, which are draughty and uncomfortable for the men. Doors at ends and sides are better, if of the counterbalanced type. When plates, flanging blocks, etc., are stored outside, a travelling crane is necessary to handle them there.

The proper arrangement for any boiler shop, whether large or small, is to leave all the middle space of the bays clear



A CORNER IN A HISTORIC BRITISH BOILER SHOP. THE RIVETING TOWER OF MESSRS. JOSEPH ADAMSON & CO., HYDE, ENGLAND

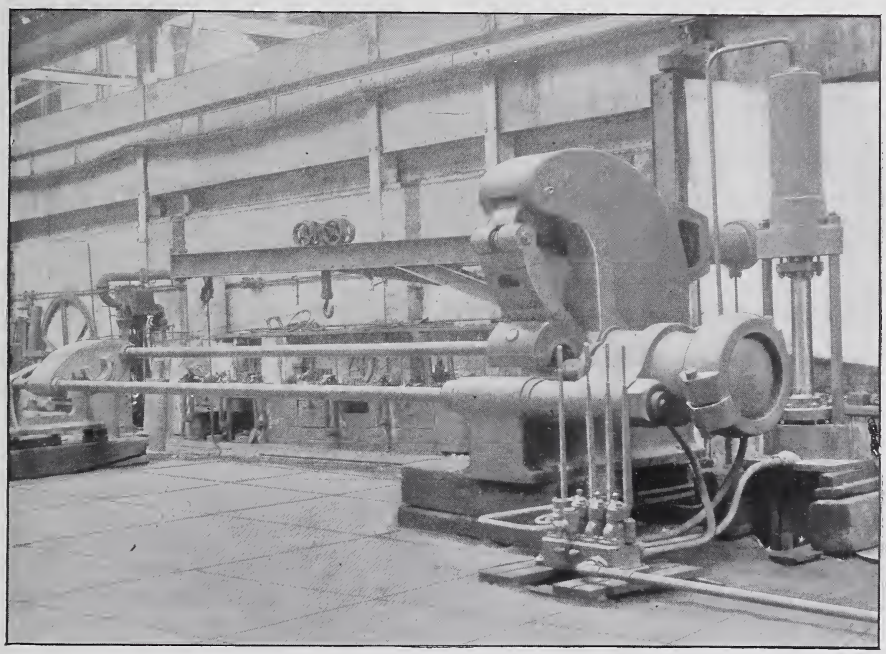
for putting work together and to arrange shafting down the walls to drive the belted machines. Machines that deal with long plates and sections are, in many cases, placed in the division between the main bays, to permit of freedom of movement; or an open area is set apart at one end specially for them.

Electric travelling cranes are the best to use for the heavy lifting down the main bays. But these must be supplemented by numerous small swinging jib cranes, since very little boiler work can be moved by hand. Crane power, in fact, should be ample. In some cases each machine will be served by its own crane; in others two or three machines may be located within the radius of a single large crane.

The boiler shop smithy is kept partly or wholly distinct from the engine smithy, because there are some details of the work which lie beyond the range of the latter. Thus the bending and welding of the angles used for flanges, the making of foundation and fire-hole rings, of calking rings for furnace tubes

and man-hole seatings, of cross tubes and uptakes, are properly the work of the angle iron smith, though, of course, there is often some overlapping of duties in shops. The forges for the angle iron smiths are ranged down one side of the shop; they are entirely open, instead of being covered with hoods, because a hood would be in the way of turning about rings and frames in the fire. The forges and the bending blocks are served by swinging wall cranes,—one to each forge,—the cranes being either chain blocks suspended from a trolley carriage on a horizontal jib, or, in the more up-to-date shops, of hydraulic types.

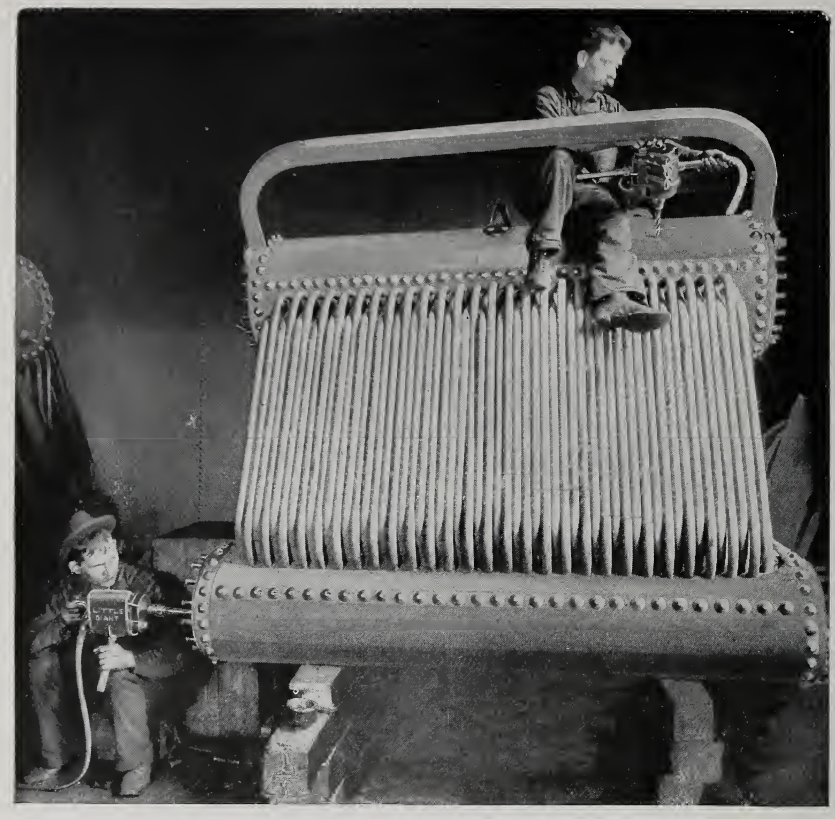
Outside of this work there is a large quantity of fittings and mountings, the forgings for which are often done in the chiefly. There is other work also which lies outside the boiler shop, such as the turning and screwing of stays, done in the machine shop, the brass finisher's work on the mountings, and the cast iron work. Water-tube boilers throw a large amount of extra labour on the machine shop, where turning, boring, and screwing have to be done with fine-gauged accuracy, while the plating and flanging that fall to the lot of the boiler makers have to be done by templet with scrupulous accuracy in consequence of the immense number of parts, the mutual fitting of which is imperative. In a marine boiler shop the screwing department is an important one, because large numbers of stay tubes and bar stays have to be screwed.



A STAVING PRESS FOR ENLARGING THE ENDS OF BOILER TUBES. BUILT BY MESSRS. FIELDING & PLATT, LTD., GLOUCESTER, ENGLAND

engine smithy, since they consist of work forged from the bar, with the assistance of dies under a power hammer, either steam or drop type. This includes the bridges of man-hole and mud-hole doors, the small fittings for furnace doors, and safety valve lever details

Machines specially designed for this work screw both ends of a tube at once, the arrangement being that of a central headstock and two saddles, much like the common duplex axle-turning lathe in appearance. Preliminary to this is the staving and swelling of tube ends,



PNEUMATIC TOOLS ON BOILER WORK. MADE BY THE STANDARD PNEUMATIC TOOL CO., CHICAGO, ILL., U. S. A.

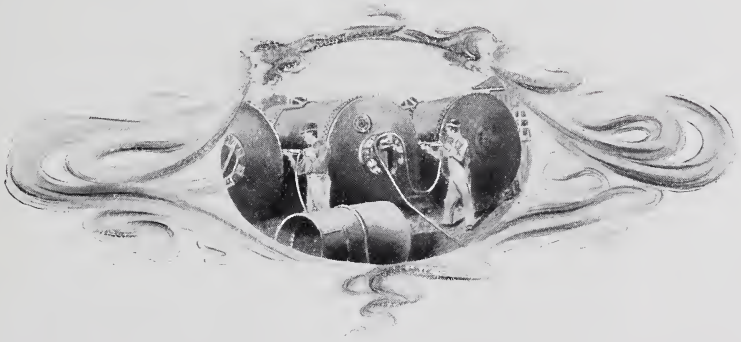
done on a hydraulic staving or upsetting press. Essentially this comprises top and bottom dies, which grip the tube end while red hot by the pressure of a vertical ram, immediately following which a horizontal staving ram enters the tube end and forces it outwards. The position of the tube is set by an adjustable stop.

In the modern shop cast iron is employed much less for fittings and mountings than it was a few years ago. Cast iron man-hole frames and covers, though an inch and more in thickness, were never found entirely reliable. The presses and flanges have nearly displaced these by stamped steel doors and flanged frames. The uses of cast iron are now nearly restricted to the following:—valve casings, stands, and seating blocks, small mud doors, dead-plates, bridges and fire bars, blow-off elbows, scum collectors, and dampers, —not a very large list, and even some of these are frequently made in sheet metal. But into the construction of some of the water-tube boilers cast steel and malleable cast iron enter.

Two classes of articles accumulate greatly in any boiler shop,—the templets and the bending blocks. It is possible to observe some order in their storage. Thus, templets all being thin, are most conveniently hung against the walls of the main shops, whence they can always be identified and are readily available; or they may be kept in a separate templet shop. Every templet should be stamped fully, using stamps of large size, to guard against mistakes in the event of changes in the personnel of the shop. Many are so much alike that confusion and error and lost time are certain to result without this ready

means of identification. The heavy blocks are laid out at one end of the shop where they can be covered by the traveller, or in a shed outside. Many, of course, are never out of use, and remain always in the open. Every block should be marked either with large stamps or an oblong space chipped out with the chisel, or stencilled at the sides, or letters may be cut deeply with a diamond-pointed chisel.

At the present time there are four power agencies in use in boiler shops. Steam and water vastly predominate; nearly all the heavy machinery is driven by these agents. Air is chiefly used for operating small tools, such as drills and calking hammers, while electricity is employed for the same purpose, and but moderately as yet for driving heavy machine tools. Steam, water, and air are each suitable for riveting, though the first has been largely displaced by the last. Water-power is adopted for heavy flanging, shearing, and punching; steam is employed for bending rolls, drills, and most of the machine tools used for cutting purposes. Any large modern boiler shop, therefore, must needs be in possession of at least three power plants, —steam, water, and air,—to which it may be desirable to add the electric motor. The applications of compressed air are growing at a phenomenal rate, being applicable to all the small portable tools used in boiler work. In large shops, in which numerous machines are widely scattered, any agency seems better than shafting and belting, and before long we may anticipate that the extension of the uses of air for small tools will be paralleled by that of electric driving for heavy tools, in place of belts and independent engines.



ELECTRIC CENTRAL STATIONS AND ISOLATED PLANTS

GAS ENGINES FOR CENTRAL STATION ECONOMY

By Alton D. Adams

IN centres of population the development of electric energy production is proceeding on two divergent lines; central stations aim to supply electricity to all consumers; isolated plants generate it for their own exclusive use. As time goes on, the isolated plant does an increasing portion of the electric lighting in the business parts of towns and cities, while the central station supply is more limited to small consumers.

Locating isolated plants and central station mains on the maps of large cities, it is found that those parts where the provisions for public supply are most ample contain the greatest capacity in private installations. This is due to the fact that in spite of the great advances that have been recently made in the economy of operation of large central stations, by using water-tube boilers, economisers, compound condensing engines, large units and direct connection, the rates for public electric supply are still much above the figures necessary to secure the loads operated by isolated plants.

Considering the economies incident to the production of very large amounts of energy at one point, it is evident that some powerful factor is operating to deprive central electric stations of what might be their largest and most valuable loads. A cause for the existence of isolated plants is not to be found in exorbitant central station profits, as is readily seen from the fact that the most prosperous electric plants pay only a very modest dividend, while far too many pay none at all. Under the present general conditions of operation the fact seems to be that the lowest rate an electric station can afford to make for electric energy is materially above what the user of a large isolated plant can afford to pay.

The true reason for much of the inability of the central station to compete with the electric isolated plant must be found in the conditions under which energy is developed and the extent to which it does useful work in each case. Starting with the central station which derives all of its energy from coal, it appears that, with the best possible steam and electric equipment, operating under ideal conditions as to amount and uniformity of load, only about 11 per cent. of the energy of the coal is delivered as electric current at dynamo terminals, all of the remainder escaping as useless heat. Allowing for the additional losses of practical operation, due to partial and fluctuating loads, storage batteries and transmission lines, the actual delivery of energy to consumers can hardly exceed 9 or 10 per cent. of that derived from the fuel.

An isolated plant with first-class boilers and an economiser generates steam containing 75 per cent. of the total heat from the combustion of coal. Engines to drive dynamos and for other purposes usually show a smaller individual efficiency than do those in large central stations, but during six months of each year engine efficiency is of small moment in isolated plants, because the exhaust steam is available for heating purposes. When all the exhaust steam is thus used, the efficiency of the complete equipment is nearly that of the boiler plant, the only further loss being that in hot water. The small percentage of its total heat extracted from steam by

passing through engines to drive dynamos is about as effective for building heat in electric lamps as it would be in steam pipes.

Comparing the part of the energy of coal available in isolated plants with the percentage that central stations are able to deliver to consumers, the reason for the inability of public supply to compete with private production is obvious. For a given amount of consumed coal a central station delivers to customers only one-seventh of the energy they can secure from an isolated plant, and its charge per unit must, therefore, be greater than the cost of operation for such plant. The consumption of energy at buildings includes that for light, heat and power. So long as each building must have developed within it, by combustion, the necessary heat, there is in the case of very large plants but slight inducement to draw energy for light or power from an outside source, since the increase in fuel consumed is only trifling when engines and dynamos are added.

It is, of course, true that during about one-half of each year buildings do not require to be heated, but the time of no heat is also that of least light, and a rate cannot be had from central stations during the summer months that would warrant idleness on the part of existing isolated plants. In order that the large and desirable loads now operated by private lighting plants may be shifted to the public supply, it is necessary, not only that the rates of electric energy for light and power be lowered, but also that central stations distribute heat at a less cost to consumers than that at which they can produce it. It seems at once obvious that a public supply system which distributes only one-seventh as much of the energy from the combustion of coal as the private consumer is able to secure from an isolated plant will never be able to offer energy cheaper than the plant can produce it.

If, then, central stations are to secure the light, heat and power loads of large buildings, a way must be found to distribute for public use a much larger percentage of the energy from the combustion of coal than is now common. Only a glance at the conditions of operation in electric generating stations is necessary to show where the most serious loss of energy occurs. The best boiler plants generate steam that contains about 80 per cent. of the heat energy in the coal burned; and large electric generators deliver the equivalent of fully 90 per cent. of the mechanical energy supplied to them as electric current. In contrast with these high efficiencies, the steam engine changes, at best, about 15 per cent. of the heat in steam entering its cylinders to motion at the shaft. Of the heat contained in boiler steam, 85 per cent. is thus lost in engine exhaust, and this amounts to $0.80 \times 0.85 = 68$ per cent. of the total heat developed by the combustion of coal. It is at once clear that if electric generating stations are to secure the large heat, light, and power loads of large private plants this great portion of the energy of coal in engine exhaust must be gathered up and delivered to consumers.

As far as can now be seen, the only form in which a large part of the energy at present wasted in exhaust steam can be delivered to consumers is that of heat. Fortunately, however, heat is a form of energy for which there is a much greater demand than all of the exhaust steam from existing electric stations can ever supply, since it requires much more energy to heat a building than to light it with electric lamps. The use of heat from exhaust steam is that which gives the isolated light, heat, and power plants their great advantage over central electric stations, and the ability to distribute the heat from exhaust, by multiplying several times the energy sold per ton of coal consumed, should materially lower the cost of public supply.

When the ease is considered with which private plants make use of their exhaust steam for heating purposes, it seems remarkable that so little has been done by electric stations to distribute their largest product of energy for public use. The fact is, however, that there is at least one very important obstacle to the general distribution of the heat in exhaust steam, and, unfortunately, this

difficulty has rather increased than diminished with the development of electric stations and supply. Central stations, when inaugurated less than a score of years since, were of small capacity and were usually situated close to the limited areas for which service was intended. This was especially true for those plants that were intended to supply incandescent lamps for interior lighting. Since those pioneer days the tendency has constantly been to extend the area supplied from a single station, and in many cases to purposely remove the generating equipment to distances of several miles from the service district.

This removal of electric stations to considerable distances from the territory where their outputs must be sold has been the natural result of a desire to increase the plant output by hardly more than 5 per cent. of the total energy of coal consumed. To gain this increase of 5 per cent, of the energy of coal in the electrical outputs of stations, the opportunity to distribute a large part of that 68 per cent. of the heat from combustion that escapes with the exhaust steam has often been sacrificed. The 10 per cent. of fuel energy that central stations deliver as electric current may be readily transmitted to considerable distances with a small percentage of loss, but the heat of exhaust steam, representing more than 60 per cent. of the total amount from combustion, is much more limited in its radius of application.

An isolated plant for a single building may have all of its exhaust steam devoted to heating purposes without appreciable loss. If an adjoining building is also to be heated, this may be done with almost equal facility. Other buildings, a single block distant from the plant, may be heated at a small disadvantage, which rapidly increases with the distance of transmission until, at a radius from one-half mile to one mile, the investment, depreciation and losses become so great as to be prohibitive. Distance is thus the controlling factor in the distribution of the heat from exhaust among the customers of an electric generating station. Some of the early central stations that have adhered to locations adjacent to their service areas are selling heat from their exhaust steam, but in most cases far too little attention has been paid to this most important source of revenue.

Two methods are in limited use for the distribution of the heat from engine exhaust at electric generating stations. According to one plan, the exhaust steam is discharged into a pipe system extending over the area to be served. The practicable radius of operation for this system seems to be limited to several hundred feet from the power station. Another method is to use the exhaust steam to heat water and then to pump the hot water through pipes that make a complete circuit between the station and the service points. Just how far from the station this hot water system may be economically extended must depend, to some extent, on circumstances, and still remains to be demonstrated. It seems certain, however, from results thus far attained, that hot water heating may be profitably carried on at a distance of half a mile and possibly at one mile from the generating plant. Some advantages of the system of heat distribution by hot water are the smaller sizes of pipes required for a given rate of work, the smaller losses of heat from the piping system, and the ease with which an excess in the amount of exhaust steam may have its heat stored in the large mass of hot water for later use.

The great importance to central stations of a satisfactory distribution for their large heat product, as well as for their small electric product, is now more generally felt than formerly, and on the solution of this problem must depend the ability of central stations to displace isolated plants. Unfortunately for the cause of heat distribution, if not for that of central station revenue, the present tendency is to remove electric generating stations so far from their service areas that the distribution of their heat from exhaust becomes entirely impracticable. This tendency is especially marked in large cities where the demand

for heat is the greatest and large isolated plants are most numerous.

If central stations are to sell the greater portion of the heat as well as the electric energy that they derive from coal and thus reach a position where they can seriously compete with large isolated plants in the supply of light, heat, and power, it seems certain that the electric generator and its driving engine must be moved back to the vicinity of the area to be served. The many objections to a number of steam plants scattered over a thickly populated territory, as to fuel and water supply, removal of ashes, value of ground area occupied, smaller economy of power production as to coal, and the increased labour attendance, all have their weight; but the isolated plant, though hampered in all of these respects, still wins in competition with central stations that distribute as electric current only 10 per cent. of the energy in coal.

Happily, however, it is not necessary to bring boilers and a complete steam equipment to the electric generating station. The steam engine must be quite close to its boiler, for economical results, but gas engines may be located some miles from plants where the gas is produced without serious effect on the economy of power production. Electric generating stations driven by gas engines are especially suited to crowded areas by reason of the relatively small amount of room that they require. The problem of transportation for coal and ashes is absent with them, and the only water required is that for cooling engine cylinders, this water being cooled and subject to loss only by evapouration.

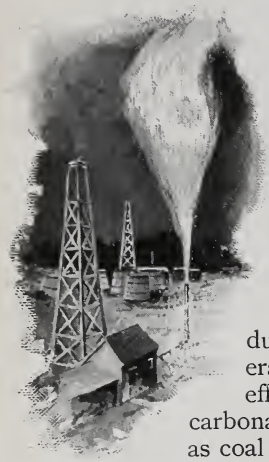
Owing to the ease with which gas is transmitted through pipes, the plant for its production may be located where all of the possible economies as to transportation, water and the labour of operation may be practiced, and such a plant may supply electric generating stations over a very large area. The efficiency of gas engines, which ranges from 20 per cent. in small engines to 25 per cent. in large sizes, allows a delivery of from one-third to two-thirds more electric energy for the same coal consumption than does the steam engine with its efficiency of 15 per cent. Having made this positive gain of efficiency in the production of electric energy, the gas engine delivers the remaining heat from its internal combustion in a form that can be readily utilised. For gas engines of medium size the distribution of heat may be fairly taken as:—delivered work, 20 per cent.; conduction and radiation, 10 per cent.; jacket-water, 40 per cent.; and exhaust-gases, 30 per cent. of the total heat produced by the gas consumed.

The temperature of the jacket-water may well be about 150 degrees Fahr., and that the of exhaust gases 700 degrees Fahr. These hot exhaust gases can readily be used to raise the temperature of the water from the cylinder jacket to 212 degrees or even a higher point, and thus fit the water for heating purposes as well as can be done with exhaust steam. This hot water may be pumped through a system of hot water mains for general heating purposes, the return flow passing again to the cylinder jackets and the coils exposed to the exhaust gases. With gas that contains 80 per cent. of the energy in the coal, the jacket-water and exhaust gases just named contain $0.80 \times (30 + 40) = 56$ per cent. of the heat of coal, or about 10 per cent. less than exhaust steam.

Gas engines and producers, in connection with electrical supply, not only increase the percentage of fuel energy delivered at dynamo terminals over that possible with steam, but greatly facilitate the location of electric generating stations where more than one-half the heat of the coal can be distributed for public use. The ability, finally, of central stations to displace private plants for light, heat, and power is not only desirable from the station standpoint, but the low rate which such ability presumes is of great importance to the general public.

THE DIMINISHING NATURAL GAS SUPPLY IN THE UNITED STATES

By George E. Walsh



THE discovery and development of the natural gas industry in the United States have been, to a large extent, coexistent with the remarkable history of the oil fields, the resources and wealth of which have furnished the basis for great industrial revolutions in several departments of human effort. Depending upon carbonaceous deposits, such as coal and petroleum, for its formation and existence in the underground reservoirs, natural gas must, to a certain extent, be limited by the amount of the latter in the earth, and the mining of either mineral to the point of exhaustion must, of necessity, cause a diminution of the gas supply. The generally recognised fact that this important lighting fuel is diminishing rapidly in supply in many of the old fields has caused no little speculation as to the ultimate effect it may have on many important industries. Both as a fuel and an illuminant natural gas has become so important that its sudden exhaustion would cause considerable loss and discomfort to thousands of people.

When the gas wells were first opened, and the fuel was utilised for lighting and heating purposes, it was generally understood that the element of uncertainty in its existence was always present. It could not be expected that the supply would forever issue forth from the openings in the earth, especially when great pipe lines were constructed to utilise all that could be obtained. But the continuance of the supply for many years induced capital to invest more and more in gas wells, and elaborate systems of pipes were laid to conduct the natural gas to distant cities. It is pretty evident that the original investors in these pipe lines received more than sufficient profit to reimburse them for their initial outlay of capital, and upon this theory the complete cessation of the flow of natural gas would probably not cause an actual loss from the beginning to the present.

The stability of some of the natural gas wells in the older parts of the world has been used as an argument by some for accepting the belief that the supply is practically inexhaustible. On the shores of the Caspian Sea the "eternal fires" of Baku have been burning from remote ages; in fact, no man knows when they did not burn. These fires are due to a supply of natural gas issuing from large petroleum deposits. In China, in the province of Szechuen, a natural illuminating gas, obtained from beds of rock salt, has been utilised for ages for lighting purposes, and the supply continues to-day almost as strong as it was a century or two ago. There are several gas wells in Russia that have likewise been burning for generations past, and there are in them no signs of diminution of supply. From these and other examples it might be inferred that the supply of natural gas in certain well-favoured regions is likely to continue almost indefinitely.

The United States have been the greatest field for natural gas in the world, and in Pennsylvania, Indiana, Ohio, West Virginia, and New York State the supply has been as remarkable as any other resources of the land. One of the first gas wells in the United States was opened in 1859 at a depth of 450

A BURNING GAS WELL. FIFTEEN MILLION CUBIC FEET DAILY CAPACITY

feet, and for twenty years it flowed uninterruptedly without a sign of failing. Several other large wells opened in the middle of the present century showed similar remarkable powers. The subsequent discovery that the natural gas supply extended over a wide territory attracted considerable capital to the coal and petroleum fields, and the construction of pipe lines from the wells to the cities followed rapidly. The latest official reports made up to the beginning of 1898 show that there are over 13,000 miles of pipes in the United States used exclusively for conducting natural gas from the wells to cities and factories. Pennsylvania has, according to these figures, 5354 miles of pipes; Indiana, 4399; Ohio, 1799; West Virginia, 893; and New York, 414 miles. Through these pipes enough fuel and illuminating gas passes annually to replace about fourteen million dollars' worth of coal and wood. In 1897 the cash value of the natural gas consumed was approximately put at $12,754,370. This amount gives one an idea of the importance of the industry that has been built up by the supply of the gas.

But this only approximately represents the value of the gas supply. No consideration is taken of the revolution that its stoppage would cause to numerous industries and the amount of new capital that it would be necessary to invest in new plants. There are a number of cities entirely or partially illuminated with the gas, and it would cause a serious financial disturbance to have the source of the supply suddenly cut off. Pittsburgh, Erie, and Liverpool, Ohio, as well as many smaller cities, have few other illuminating plants to fall back upon in an emergency, and the exhaustion of the gas wells would necessitate the erection of large artificial gas works. But in late years the natural gas has entered into the fuel problem fully as much as into the illuminating question, and it would be this side

of the problem that would cause serious trouble. Many of the great iron and steel works in and about Pittsburgh depend, to a large extent, upon the natural gas for their fuel, and several have their individual pipe lines extending to

THE TUBING WAS BLOWN OUT OF THIS WELL AND THE GAS CAUGHT FIRE, DESTROYING EVERYTHING NEAR IT

the fields. In the oil regions gas is used as a fuel for the pumping plants, and numerous factories of all kinds find their fuel and illuminating power in the same way. The consumption of natural gas has thus increased rapidly, and its diminution would involve many industries besides that of illuminating cities and private houses.

There has, however, been a gradual reduction in the waste of the gas, which partly compensates for the increased demand upon the supply for manufacturing purposes. When the gas was in its early stages of development its waste was enormous. The gas lamps in some of the cities were never extinguished. Gas wells were carelessly set on fire and burned for months and years without any attempt being made to extinguish them. The burning wells were advertised as remarkable pyrotechnical displays to attract visitors to the gas regions, and some were purposely set on fire to add to the brilliancy of the scenes. In this and other ways the gas was wantonly and extravagantly wasted. It was believed by some that the supply was inexhaustible, and that its formation in the bowels of the earth would proceed as fast as man could use it up.

This is not the view entertained to-day, and companies operating the extensive pipe lines and owning gas wells are adopting every possible method of preserving the supply. The exhaustion of one well after another, and the diminution in the pressure of gas in others, have served as distinct warnings that must be heeded. The discoveries of new gas wells continue to-day, and distinctly new fields are being opened up from time to time; but the time is approaching when no more gas fields will be left undeveloped, and the supply will have to be carefully husbanded.

The resources of natural gas are still enormous, magnificent indications of the prodigality of nature, but the supply is undoubtedly on the wane. This is susceptible of proof by the recent statistics compiled by the United States Geological Survey. These point to the inevitable conclusion that the demand has rapidly multiplied, both for fuel and illuminating purposes, and that the number of new wells opened in the past ten years has decreased and the supply of many of the old wells has steadily declined. In some regions the exhaustion is so great that preparations are

AN OIL TANK STRUCK BY LIGHTNING

being made to abandon the works, and the end of the supply may come within the next few years. In other locations new wells have been opened in great numbers, but in few instances is the pressure anything like that which startled the world back in the seventies.

To be more specific, we find that the supply of natural gas in Indiana has not declined, nor has it increased any in the past few years; but the pressure throughout the State has fallen from 325 pounds to 195 pounds in the past ten years. Thus, in spite of the opening of many new wells, the supply has remained about stationary. There are few new factories or mills in that State availing themselves of this natural fuel, for it is reasonably expected that any great additional demand on the resources of the wells would precipitate their exhaustion. The average pressure of the natural gas throughout the State was put at 181 pounds to the square inch in 1898, and it is predicted by the State Geologist that when the pressure drops to 100 pounds the majority of the wells will be of little practical use. When it is remembered that most of the Indiana wells draw their natural gas from the Trenton limestone from a depth of no less than 1000 feet, the importance of this decrease in the pressure becomes more emphatic.

In the leading natural gas State of the Union the conditions are even more unsatisfactory than in Indiana. The Pennsylvania wells are larger and more numerous than those in any other part of the United States, and they supply light and power to more cities, towns, and factories than those of any other part of the country.

In 1888 the natural gas "boom" in

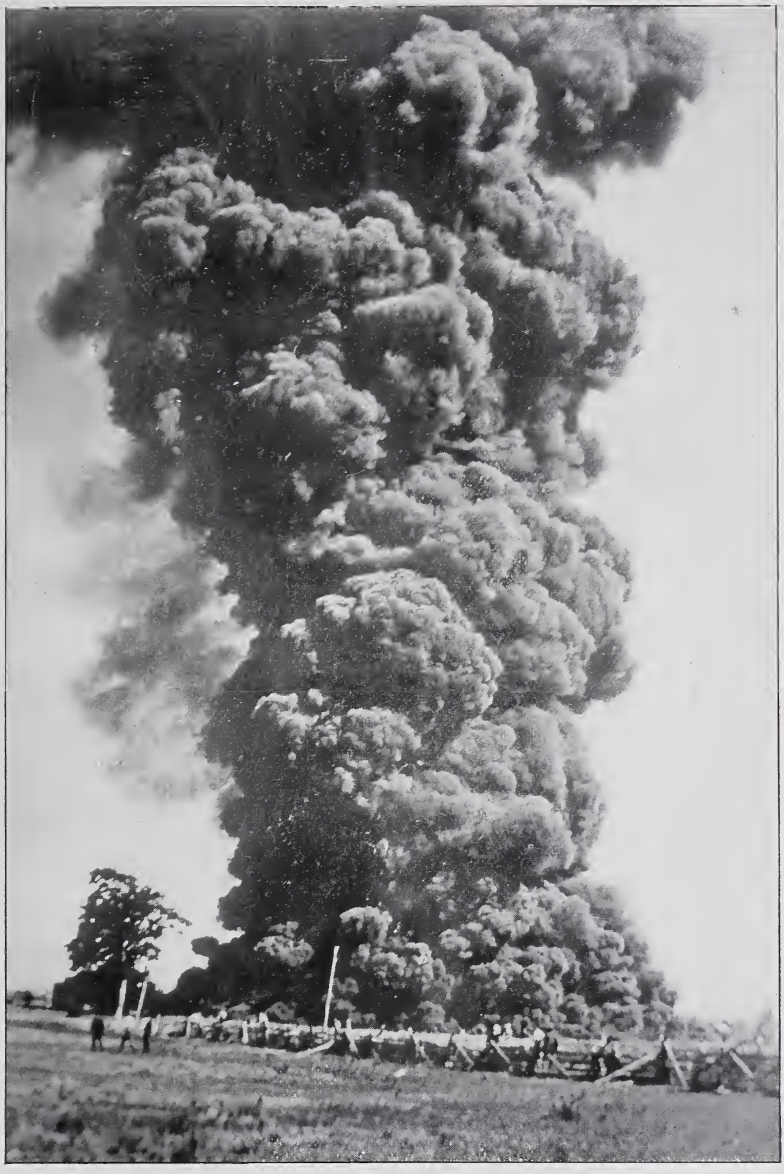
Pennsylvania reached its height, and the value of the product used was nearly $20,000,000. In the city of Erie alone there were thirteen wells, each yielding from ten to thirty thousand feet of gas per day. Several thousand wells were scattered throughout the State, and the pressure varied from 150 to 300 pounds to the square inch. From 1888 to the present the supply has been steadily decreasing, and the demand increasing. In 1897 the value of the product was placed at $6,242,543, a fall in one decade that is most alarming. There are to-day considerably over 2000 gas wells in that State producing, and a thousand or more practically abandoned. Formerly the percentage of new wells drilled that produced gas in paying quantity was very high, but in 1897 over 96 drills were made without striking gas. In that year over 147 wells were abandoned, and 314 productive ones were opened. The pressure has fallen decidedly, and it is necessary to increase the size of the wells in order to secure the gas in paying quantities. In many wells the pressure has fallen to such an extent that gas pumps must be used to keep up the desired supply.

Improvements for preventing waste of the gas have made more progress in Pennsylvania than elsewhere, and everything is done to economise in the sale and distribution of the product. The use of meters is quite general, and it is believed that one cubic foot is now employed for lighting or heating where three feet were formerly consumed. The difference between the two actually represents the amount of waste that was formerly permitted. Unless more wells can be opened and made productive, the supply must diminish, for the steady decrease in the pressure makes it more difficult to secure the same amount except through the introduction of pumping machinery, which also increases the cost of production.

In Ohio the natural gas supply seems to be increasing in some districts because of the opening of new wells, and steadily declining in many of the older worked sections. Thus in recent years an entirely new gas field has been discovered and developed in Fairfield County, and the supply is found to be very good. The pressure is remarkable, averaging as high as 800 pounds to the square inch in many wells, the gas coming from a depth of over 2000 feet. New wells are rapidly being opened in this section, and each one proves very productive. The gas is carried in pipes to the principal surrounding cities. There are no signs of any diminishing pressure of the gas from these new wells, but that may be due to the fact that they have not been operated long enough to make a test of their ultimate productive capacity.

A very different story is related of the condition of the wells in other parts of the State. There has been a steady decline in the amount of gas produced as well as in the pressure. The latter in some parts of the State declined from 450 pounds to the square inch in 1888 to 30 pounds in 1897. This decrease in pressure has caused the abandonment of many wells and great difficulty in working others at anything like a profit. In 1897 the State geologist reported 688 gas wells in activity in Ohio. During the same year 88 wells were drilled that proved productive; 51 were drilled that were not productive enough to continue operations; and 59 old wells were abandoned. The decline in the value of the State's output of gas in ten years has been about four million dollars.

West Virginia is a more recent competitor in the natural gas supply, and the industry is almost too young to draw any conclusions from the statistics that have been thus far gathered. There is a promising field in that State for the development of this resource of the earth, and it may be that the losses sustained in some of the older fields will be partly made up in the extra supply found in West Virginia when her resources are better known. New wells are being driven rapidly, and new industries are springing up to utilise this agent as a cheap fuel. Most of the drilling extends from 1200 to 2800 feet down, and there are now about 200 wells in the State. The flow is remarkably good, and in some the pressure



THE SAME TANK FULLY ON FIRE

reaches over 1000 pounds to the square inch. This enormous pressure indicates an abundance of gas in the lower reservoirs that may yet be released in such quantities that the new fields will rank first in the world.

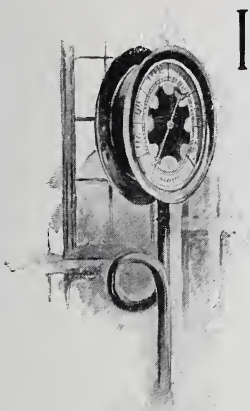
It is possible that new and unexpected gas fields will yet be discovered in parts of the West of the United States not yet drilled or in any way suspected of having any of this remarkable natural product. In Canada, for instance, wells have been discovered in recent years, and Canada's supply of natural gas is already a formidable factor in the fuel supply. In the past few years great quantities of the gas have been piped from that country to the

United States, and a number of cities and factories near the border line are using it. From examinations made by experts it is evident that Canada will prove a great natural gas producer in the near future. The supply seems to be there in immense quantities, but there is no local demand for it to remunerate the owners for drilling the wells. It requires the settlement of the country within comparatively short distances of the gas fields to make the product of special commercial value. In the early days of the development of the natural gas wells the product was used almost exclusively for illuminating and heating purposes in towns and cities, and the employment of the gas as a fuel in factories and iron and steel works marks an entirely different phase of the subject. There has been an actual decrease in the use of natural gas in Pennsylvania for domestic fires, but manufacturing concerns have greatly increased their employment of it, and hundreds of modern plants have been equipped with pipes for using the fuel.

The decrease in the gas supply during the past decade has been so pronounced that, at the present rate of consumption, the limit will soon be reached. Fewer wells are being drilled every year, and the demand cannot be met by the introduction of new machinery and the use of meters and similar inventions to prevent waste. It might be more profitable in the end to limit the use of the natural gas to light manufacturing purposes, and this would postpone the exhaustion of the fields for a considerable period. Present indications point toward the gradual adoption of this idea.

THE POWER IN A POUND OF COAL

By E. D. Meier



IT has, no doubt, been observed by many that when we strike a nail a number of rapid blows with a hammer in driving it into wood, both nail and hammer become warmer. If we could measure the exact quantity of heat which has thus been imparted to the nail and hammer, we would find it to be equal to the muscular force which drove the nail in. We took so much heat out of our body and changed it, by the will of our brain, into muscular exertion. It did its work at our bidding in driving the nail home and we find it again in the metal.

We see the same thing when we cut off a sliver of iron with a steel tool in a lathe or planer. We are often compelled to let water drip on the piece, because otherwise this heat would accumulate too rapidly to be carried off by the natural conductive power of the metal. Observations such as these led to determining certain units of heat and mechanical force and showing their relation to one another. If you raise a weight of one pound to a height of one foot you have done a measure of work, and this measure or unit is called a foot-pound. If you raise 100 pounds one foot high, you have done one hundred times as much work, and this will be designated as 100 foot-pounds. If you raise 330 pounds one hundred feet high in one minute, you have done 33,000 foot-pounds of work in a minute, and this is called one horse-power. Observe that here a new factor has come in, viz., time; and in all mechanical work we must consider the element of time. When we have weight, distance, and time we have the three elements which constitute a measure of work by which two men, or two horses, or two machines can be compared. This had been done for some time before men began to realise that there was a distinct relation between such units of work and quantities of heat.

Count Rumford first attempted to measure this by determining the quantity of heat which was evolved in the boring of a cannon at the arsenal at Munich, Germany. Other observers followed him, and finally adopted what is known as the mechanical equivalent of heat, namely, 778 foot-pounds. This amount of work was found to be exactly equivalent to the quantity of heat necessary to raise one pound of pure water from a temperature of 62 degrees Fahr. to that of 63 degrees Fahr., or, roughly speaking, the quantity of heat required to raise one pound of water one degree Fahr. in temperature. Note here the distinction between difference in temperature and quantity of heat! Temperature is measured by the thermometer; quantity of heat is always referred to the unit just mentioned, known as the British thermal unit, or, more generally, simply the heat unit. It is easy to remember, then, that a heat unit is the quantity of heat required to raise one pound of pure water one degree Fahr. in temperature, and it is as much a tangible reality and a measure of quantity as a foot or a pound.

When the chemist wants to determine the power contained in one pound of coal, he simply crushes his coal to a fine powder, takes a small quantity of it which he carefully weighs, and which, by chemical means, he burns under water. Having previously determined

the exact weight and temperature of this water, he finds its temperature after this quantity of coal has been burned in it, and then figures out that if the small pinch of coal which he burnt adds so much temperature to the small quantity of water, a pound of the coal will add a proportionate quantity to a larger weight of water. This is one of the most important determinations which can be made of the coal which we are using under boilers. Almost everything else that we buy has its price based on its quality as well as on its quantity. But in many a large factory or power house it requires vigorous effort on the part of that practical chemist generally known as the fireman or stoker before the manager will look into the quality of the coal which is delivered to him.

It is true that the fireman who daily handles the coal learns roughly to judge of its quality by its appearance and its action on the grate. But its actual fuel value, on which its market price should be based, can be determined only by the method indicated. When we remember that there is a difference of over 50 per cent. in the heat value of different coals, and that it is easier to get a large percentage of this heat value in useful work from a good coal than from a poor one, we must realise that when a good fireman grumbles at the quality of the coal, he is, in all likelihood, doing his employer a valuable service.

Let us, for the purpose of what follows, take a pound of what we will call average coal, containing, say, 10,000 heat units. This would be somewhat smaller in size than a man's fist. If we could burn this pound of coal completely and entirely under water, and let all its heat go into the water, we could raise the temperature of 625 pounds of water 16 degrees.

Picture to yourself that you have a bath-tub five feet long, two feet wide, and filled one foot deep with water, and that this water has a temperature of 64 degrees. If the pound of coal could be completely burned in that water and all the heat thereby evolved could be imparted to this body of water, the latter would have become 16 degrees hotter, *i. e.*, it would be a comfortable bath at 80 degrees Fahr. This does not seem like very much work, but it gives a fair measure of the quantity of heat which slumbers in the lump of coal.

The ten thousand heat units in this one pound of coal which we found sufficient to warm our bath, if expended in mechanical work, would give us 236 H. P. We are all more or less familiar with the term horse-power, and we often use it without thinking, or without realising what it actually means. Watt, the father of the modern steam engine, found that a strong brewer's horse could, during eight hours, do work sufficient to raise 330 pounds 100 feet high in one minute, and hence he called this quantity of work performed in this time one horse-power. We must remember, however, that the horse will not be raising constantly, for after each hoist the rope and hooks must be again lowered, so that scarce four out of the eight hours are actually spent in the active work of hoisting. We have, therefore, hidden away in this one pound of coal the full day's work of a strong Percheron horse. Note the contrast between the comparatively small effect of warming one comfortable bath and the large one of raising nearly 40 tons of merchandise or material a height of 100 feet. A few more illustrations will show how much more effective the work of this pound of coal seems when applied to some mechanical problem than when used for what would seem, on first thought, its proper office, that of giving warmth.

The snowfall in winter often seriously impedes travel on city streets, as well as on railways. This has led inventors to study out and patent a number of devices intended to melt away the snow. The fallacy of this mode of proceeding becomes apparent as soon as we figure out what a pound of coal can do in that way. It takes 142 heat units to melt one pound of ice or snow when this ice or snow is already at 32 degrees. If it is colder, it will take as many more heat units as are required to first bring the snow to this melting temperature, known as the freezing-point. Therefore, when the snow is just ready to

melt, the heat in the pound of coal is just sufficient to melt 71 pounds of snow. This is less than one-third of an ordinary cart load. But we have just seen that this pound of coal carries within it the power of 236 horses, each of which could easily pull 30 times as much snow, if loaded in a waggon, than this one pound of coal can melt.

Again, the 236 H. P. of potential energy which we know to be slumbering in this pound of coal would do the work of an express locomotive for one-fifth of a minute. In other words, it is enough to haul a train of eight cars, including Pullman sleeping cars and dining cars, at the rate of fifty miles an hour one-sixth of a mile. It is enough to haul a cable train at the rate of nine miles an hour, including the grip car, the trailer, and its quotum of moving cable, a distance of nearly two miles; and it is enough also to pull an electric motor car, loaded with passengers, at the rate of ten miles an hour, a distance of two and one-half miles.

One more illustration! We warm our workshops, our offices and our assembly halls by steam heat. It takes comparatively little to simply warm the walls and keep up, or make up, for that outflow of warmth which goes on through the closed windows, through doors, walls and ceilings. The more important thing is to warm and supply enough air so that it may remain fresh and wholesome to enable each man to do his best work. This means the heating of about 2120 cubic feet per hour for each man, or the equivalent of the contents of a room about 10 feet high, 12 feet wide, and 18 feet long. This seems a large quantity of air for a single individual, but experiments show that with a smaller supply the air becomes vitiated. We have, then, in this one pound of coal just heat enough to supply the hourly requirements in fresh, warm air of three men and a third over.

Again, let us suppose the energy stowed away in this pound of coal transmuted to an equivalent quantity of actual mechanical work in raising elevators in some large building. We will suppose our elevators to run at the rate of 200 feet a minute, and each to be loaded with eight persons of medium weight. This little lump of coal holds power enough to run 32 of them at a time, enough to put 256 people up to the top floor of these buildings five or six times as fast as if they had to walk and without any effort of their own.

Let us now compare the power imprisoned in this black diamond with the work of a strong man accustomed to hard labour. Many observations show that such a man can do, as an average, about one-tenth of a H. P. Allow him eight working hours, equal to 480 minutes. During this time he occasionally stops for short rests, to change his position, to pick up another tool, to judge of the result of his work and plan for further procedure. This will easily consume one-tenth of the time, leaving 432 minutes, which, at one-tenth of a H. P., gives him a total effect of 43.2 H. P. as the result of his day's labour. This pound of coal contains more than sufficient power to do in one minute the day's work of five such strong men. Or it would take about 2600 strong men, working steadily side by side, to do jointly as much work in one minute as nature has locked up for us, ready at our call, in a single pound of coal.

Imagine at the time of the Pharaohs two long lines of men, extending over half a mile, all pulling steadily, at the command of the task-master, at a great rope to raise some huge obelisk, and as you see them sweating, tugging and straining, think again of this small lump of coal in which nature has placed an equal amount of power. In some countries men who have been specially trained as porters, to carry heavy loads on their backs, will, as a full day's work, carry a total of from 350 to 600 pounds a distance of one mile. And yet each has expended but one-third of the power stored up in this pound of coal.

An exceptionally strong man has been known to do one-half horse-power of work as his mightiest effort; but in two and a half minutes' work at this rate he exhausts his muscular force. Let us suppose 100 such men putting forth

such extreme effort at rope, or crank, or crowbar; as they fall back, red-faced and puffing, to catch their breaths, we might imagine this little black lump saying to them:—"I can do as much as your whole company, and then can stand it for fully two minutes longer before I am exhausted!"

Let us now turn to another portion of the human race. From the earliest times spinning has been a much-prized accomplishment of the fair sex. We need look back only to our own grandmothers. We can picture them, from their own stories, told us when we were children, as rosy-cheeked damsels sitting around the open fireplace and spinning from early candlelight till bedtime, let us say possibly two hours. Let us then consider for a moment the thousands of spindles rattling and whirling in a modern cotton factory, impelled by the power locked up in coal. One pound of this coal carries the potential energy to do the work of three thousand such spinsters.

In sawing wood, a man may work at the rate of about 60 strokes a minute and consider himself a "top-sawyer," and his saw blade may have progressed five feet a minute; but a circular saw, driven by machinery, may be put through 70 times that distance and saw 70 times as much wood. And yet this one little pound of coal contains power enough for 180 such saws.

We have taken thus far examples of useful work. Let us consider one case of destructive energy, — energy expended, say, in the explosion of a steam boiler. We will take a plain tubular boiler 60 inches in diameter, and, say, 15 feet long. It contains about 8300 pounds of water and 20 pounds of steam, and in these, when a pressure of 75 pounds per square inch has been reached, there resides a vast amount of energy in the form of heat. When an explosion takes place, this stored-up heat bursts forth instantaneously in one vast effort of destructive energy. This massive boiler weighs nearly five tons, and yet this explosion suddenly unchains force enough to send the whole structure a mile high into the air with an initial velocity of nearly 600 feet per second.

The destruction does not always take this form. Instead of hurling the boiler as one piece into the air, it may tear it to shreds, tumble the building to ruin, kill, maim, or scald all in the neighbourhood. The writer remembers the explosion of a boiler of this size in a small electric-light station in which no large piece of the boiler was thrown more than 50 yards, but the boiler and engine rooms were simply a mass of ruins, the roof was blown away, and the walls were all thrown outwards. The engineer was found on the opposite side of the street. In a later explosion of a somewhat larger boiler, seven out of twelve boilers were thrown into the ash-pit and the station was completely wrecked. Yet this vast amount of energy is only seven times the amount which nature has kindly locked up in this one little lump of coal.

In all these previous considerations the writer has given the equivalent power actually locked up in a pound of coal. We all have some general idea of the manner in which we get it out and apply it to our purposes. In fact, there is a general, but very erroneous, impression that, since the times of Watt, Stephenson, and Fulton, anybody can do it. Very few manufacturers or superintendents realise that at the very first step, the firing of the coal under the boiler, there is necessary a careful, patient, and skilful workman; and, furthermore, that this workman deserves, and true economy demands, that the apparatus itself, the boiler, the grate, the furnace walls, the flues, and the chimney, should all be constructed according to rules and dimensions resulting from the most careful and patient investigations of the chemical and mechanical problems involved. In the time of Watt it was considered necessary to furnish one cubic foot of water per hour to the boiler for each horse-power to be delivered by the engine. While we have no reliable data as to the quantity of coal it took to evaporate this amount of water, we know enough about the kinds of furnaces, boil-

ers, and chimneys at first applied to estimate pretty closely how much could be done by them under the average conditions of practice.

It is interesting to follow this out in order to find how much of the power which nature has given us in this pound of coal we are able to get out of it, either in useful work on the main shaft of an engine, or in heat otherwise. We will find that there is a great loss between the shovel of the fireman and the useful effect finally achieved. In earlier days fully 60 per cent. of the heat in the coal was wasted in the boiler and furnace. At present, a reduction of this loss to about 25 per cent. represents the very best practice. That is to say, that if we get three-quarters of the heat which we know to be contained in this pound of coal in the steam which our boiler makes, we are doing about the best possible with our present knowledge of the subject.

From the boiler to a steam radiator for house heating we need not lose much, and even the losses in transmission become indirectly useful in heating up the basements, walls, and floors before we reach the room we desire to warm. It is different when we get to the engine. There are subtle causes of loss in heat which are difficult to locate and determine, and the greatest skill has been baffled in attempting to prevent or even materially reduce them. Therefore, the comparison previously made between producing heat and producing mechanical power does not appear so badly for the former as it seemed from the figures. These were made entirely on the basis of what is in the coal. That is what nature has done for us. When we now turn to measure how much of this we are able to utilise, we come to the conclusion that, with all our boasted advance in knowledge and skill, we are but at the threshold and have much yet to learn.

In giving these figures the writer has reduced everything to the average coal mentioned at the outset. If we take up some data given, for instance, on English or Welsh coals having 30 or 40 per cent. more fuel value than the piece here considered, we will, of course, find larger results, because there is no direct ratio between the fuel value of two coals and the results we may obtain from them. It is much more difficult to get two-thirds of the heat out of the coal here considered, for example, than to get three-quarters of it out of a better coal.

Based on this coal, then, we find that the earliest engines and boilers of the time of Watt would require somewhat over 18 pounds of coal per hour to realise one horse-power on the engine shaft. In other words, only 1.4 per cent. of the power in this pound of coal could be then realised. Only a few decades later, improvements in boilers and engines had brought this down to a consumption of 9.4 pounds of coal per horse-power per hour. We were then realising 2.7 per cent. of what nature had provided. When we come to the best types of slide-valve engines and tubular boilers, about 1876, the fuel consumption had been reduced to 5.7 pounds; that is to say, we were then realising 4½ per cent. of the power locked up in the coal. About the same time, with a good Corliss engine, the coal consumption was reduced to 4.3 pounds per horse-power; or, we were able to realise 6 per cent. of the fuel value.

This brings us down to the present time. With the same engine and a good water-tube boiler we can get down to 3.7 pounds and realise 7 per cent. of the fuel value of the coal. And wherever local conditions will permit us to go to the expense of the higher types of condensing engines, we can do considerably better. With the best form of water-tube boiler we can get a horse-power on the engine shaft with respectively 3 pounds of coal for a compound, 2½ pounds for a triple-expansion, and 2 pounds for a quadruple-expansion engine. This means that we are able to realise for actual work respectively 8¾, 9.6, and 12.7 per cent. of the fuel value of the coal.

We may now look over the whole field and draw the trial balance between what our debt is to nature and what

credit we may take to ourselves in useful work drawn from her storehouse. Out of the 10,000 heat units in this pound of coal we realise about 5000 when we use it for heating air or water through the medium of a steam boiler. By more direct methods, *i. e.*, by means of stoves, furnaces or fireplaces, we waste much more than 50 per cent.

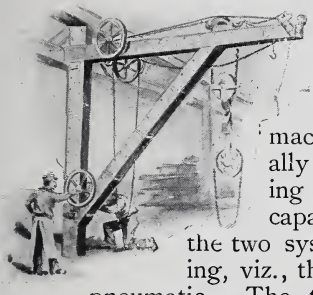
Out of the 236 H. P. nature offers us in the pound of coal we have, with our very best efforts, and after nearly a century spent in trying, been enabled to realise only 40 H. P. In most cases in our smaller industries we get only from 14 to 16 H. P., and yet, again, there are thousands of power plants, such as small steam pumps, elevator and crane engines, that give us only 5 H. P.

Instead of replacing 2600 men at the rope, which we know a pound of coal can do, we are able to make it do for us the work of only from 150 to 400 men. In place of doing the work of 3000 spinsters, we can make it release only 300 of them from the spinning-wheel.

At the very best, then, we have still a waste of 25 per cent. in our boilers and 83 per cent. in our engines. Here are two fields in which our inventive faculty, our constructive ability, or our patient daily toil may find a rich harvest. A careful survey of the path by which we have travelled shows us that these three manifestations of human ability must combine always to reach the goal. Inventors have frequently shown possibilities and died, despairing of their realisation, because neither the constructive ability of engineers and mechanics were, at the time, equal to the task of reducing their ideas to practice, nor was the average workman or labourer sufficiently educated and trained to enable him to work such invention. Thus, for instance, more than half a century ago scientific thinkers proved the advantages to be gained from very high pressures of steam, and more than a quarter of a century ago the value of superheating was shown. And to-day we are but cautiously reaching out to pressures like 200 pounds, and superheating is yet in its infancy.

ELECTRIC RIVETING MACHINERY

By F. von Kodolitsch



FOR the last two years the writer has been experimenting on electric riveting machines, and has finally succeeded in bringing out two types quite capable of superseding the two systems already existing, viz., the hydraulic and the pneumatic. The two systems which have been developed by him comprise a fixed type, to be used in the shop, for small girder, roof, railway waggon, and locomotive frame riveting, built for closing rivets 1⅜ inches in diameter; and second, a portable riveter made chiefly for shipbuilding and bridge work purposes. This latter machine is being built at present for a gap of 26 inches and for closing rivets of 1-inch diameter.

This type of riveting machine is, up to the present, the only type which really may be called an electric riveting machine. There are a number of other machines in the market which bear the name of electric riveting machines, but these are in reality ordinary hydraulic riveting machines with the compressor pump driven by an electric motor. The machines brought out by the writer are purely electrical, the power developed by an electric motor being utilised directly for closing the riveter.

Most shipbuilding yards and bridge building establishments are now seriously considering the question of introducing electric transmission of power into their works, for the sake of driving each tool by a separate motor. Some of the factories already possess a hydraulic installation for riveting purposes which it would be impossible to convert to the new system. The only way of applying the new system to the existing plant would be to drive the compressor pumps by a separate electric motor. All the defects which belong to hydraulic installation in general would, in this case, be retained, viz., a great outlay of capital, comparatively high working expenses, and a considerable cost in the up-keep.

There are a good many firms who have to decide which system of riveting they intend to adopt for the future, in order to keep pace with the rapidly increasing competition of other firms at home and abroad, and for this reason may be interested in this new system of riveting, which in most cases will offer them many advantages. For riveting small pieces of little weight it is more advantageous to use the fixed riveter and to move the piece which is to be

A SMALL PORTABLE OUTFIT

A FIXED ELECTRIC RIVETER

riveted by means of a jib crane or travelling crane from hole to hole. For large pieces, however, which weigh more than one ton, it is better to use the portable type of machine. The weight of such a riveter is only half a ton, which can easily be handled by means of a suitable crane, and it is much quicker to move the machine from rivet to rivet than to move a girder which weighs, perhaps, two or three tons.

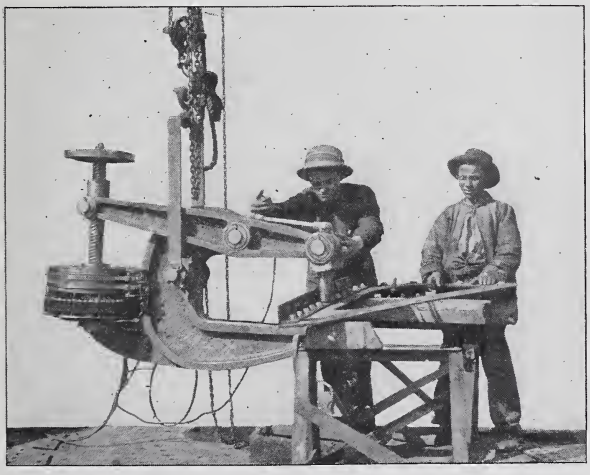
Machines of the kind here considered are specially adapted for use in shipyards where frames and reverse frames are to be riveted together. After these frames have been mounted together they may be placed on a number of small chairs, under the span of a swivelling crane. From this crane is suspended, by means of a differential pulley block, a portable electric riveting machine. This machine is arranged in such a way that the rivet head is closed down below, so that when the rivets are dropped into the holes the square head is on the top and the snap head is finished by the bottom die. Close to this swivelling crane is a small rivet heating furnace. The air blast for this furnace is supplied by an electrically-driven blower. The motor of this blower is of 1/6 H. P., and the quantity of rivets heated by such a blower is sufficient to supply two riveting machines,—that is to say, about 3000 rivets per day.

Before proceeding to describe the electric riveter in detail, it should be pointed out, briefly, why the electric system is, from the commercial and technical point of view, superior to all its rivals. It is assumed, of course, that the shipyard adopting the new system already possesses an electric plant and a system of wires for transmission of power. This is, in fact, the case in a good many establishments. If there are punching, shearing, or boring machines, and others of similar character, worked by the electric current, it is certainly logical to utilise the existing current also for riveting. Any one deciding to rivet by electricity has only to order such a machine and place it where he wants to do his riveting, connect two wires from the main to the riveter, and begin work at once.

Now let us suppose that hydraulic riveting has been decided upon. A pair of compressor pumps have to be installed, a large accumulator must be put up, and pipes laid. Pipe connections between the riveter and the ac-

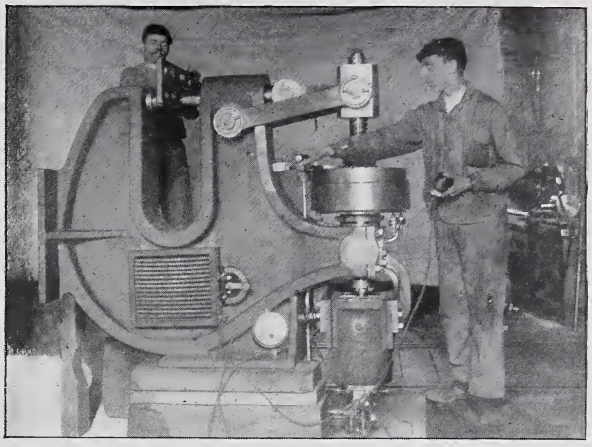
cumulator have to be made, and a hydraulic riveting machine must be bought and erected. In the case of pneumatic riveting, the same installations must be made, and almost the same outlay of capital incurred.

What has been said above clearly demonstrates that the initial outlay is far less if the electric system be adopted. Every one who works a hydraulic or pneumatic installation must know what a heavy item the keep-up is in the total working charges. In cases where the electric system is used, this, on the other hand, becomes only a fraction of the expenditure. As regards the quality of the work, there is not the slightest difference, but as regards the quantity of work done, the electric system is considerably superior. The machine here considered by the writer has closed, for weeks and weeks, 1500 rivets in a day of ten hours' duration, requiring the attendance of only three men and a boy.



A PORTABLE MACHINE

The method of working this machine is extremely simple. One heavy disk is always rotating by electricity, whether the riveter is closing rivets or not. This disk can become, at the same time, an electro-magnetic coupling, so that when the current is passing this coupling, a second disk, keyed on to a screw spindle, may be at once firmly attached to the revolving disk; thus the friction of the screw spindle can be regulated according to the operator's wish. The screw spindle moves a large nut at the end of a knuckle joint or lever, which raises and lowers the die for making the rivet head. When the rivet is put into position the operator places one die on the existing rivet head, and presses a button which allows the electric current to pass through the coil of the electro-magnetic coupling. By means of the attraction of the iron disk, which forms part of the screw spindle, the constantly revolving fly-wheel and the attracted iron disk become one piece, and the screw spindle is turned round with the whole energy stored up in the fly-wheel disk.



ANOTHER FORM OF STATIONARY RIVETER

There is an automatic cut-out arrangement by means of which the two disks may again be disconnected before the end of the travel of the nut. If the

second disk, which is keyed on to the screw spindle, has received a sufficient acceleration from the first fly-wheel disk, which is rotating constantly, the energy transmitted during two or three revolutions to the second fly-wheel is, of course, quite sufficient to finish the rivet. As the screw spindle is a four-threaded one, the pressure of 50 tons which is put on the rivet head is fully ample to make the machine reverse automatically,—that is to say, after the rivet head is closed the nut returns again into its original position, close to the fly-wheel, to be ready for the next stroke. By the construction of this machine one can see distinctly that it is perfectly indifferent whether two, three or four thicknesses of plate are put between the dies, and that no adjustment is necessary to rivet different thicknesses.

SYSTEMATIC PIECE-WORK PRICING

By D. Carnegie

SO much has been written about the piece-work system, and so little, as far as the writer is aware, about one of its important and essential parts, — the actual pricing of work, — that it may be profitable to give some account of the practical method adopted by the writer.

There are various systems of paying workmen for labour, but in each one a fair price is expected. It is rightly contended that unless the highest capabilities of a machine to produce any article be known, it is impossible to accurately fix the price at which the work should be done to the profit of both employer and employee. The system of guess, or "I think that the article is worth so much," is defective, even though the experience of the one who is setting the price has been considerable in machine work.

There are so many things which may influence a man while pricing work that the safest plan is not to trust only to experience, but also to a standard, calculated from experiment. Workmen who know that their prices are fixed only from a man's practical experience are not likely to be contented if they find their prices low when their articles are completed. On the other hand, when workmen know that prices are fixed in a systematic manner, based on a uniform system as far as practical, they feel sure that the prices are right to begin with, even though they may appear too low for the articles. This assurance gives the men courage to proceed energetically with their work, and fosters contentment.

Much is said about the necessity of the employer working in harmony with his employees, and no one will question the advisability of this who knows that if once such harmony ceases in the workshop the output of work diminishes, and need arises for increased supervision. But one certainly objects to the employer working in concord with his employees at the expense of production, simply for the sake of peace. It is too evident to admit of dispute that in the piece-work factory harmony can be best established and maintained when a proper understanding exists between master and men; and this can be only when the men realise that their work is paid for according to a fair standard, with the prices calculated from a system

thoroughly tested and proved. What a man should earn per week is not the question under consideration, but a fixed value for skilled and unskilled labour must be laid down by the master; otherwise, the systematic determination of a price for any article becomes impossible. Once the value of the work is determined, the next essential is to find the actual time needed for doing the work. Herein lies the difficulty, especially in a factory where work constantly changes. In order to accurately estimate the time required for doing any class of machine work, it is necessary first to know the maximum speeds at which the various materials can be cut with the least expenditure of power; this necessitates, further, the knowledge of the best angles for the cutting tools, so that they may be used under conditions of greatest efficiency.

It is not only essential that the master, or the one who has in hand the calculating of the prices, should know these details, but it is as important for the machinist to know them. As to the best speeds at which to run a machine tool for cutting any material, a small plate should be attached to each machine, upon which are stamped the names of the various materials used, and opposite them the number of revolutions for materials of 1″ diameter. Having all speeds reduced to 1″ diameter, the least intelligent machinist may easily find the speed required to cut any diameter of material by simply dividing the number of inches in the diameter he wishes to cut by the number of revolutions given in the table for materials of 1″ diameter. The result, of course, is the required number of revolutions. Having found this, it is also necessary that the man should know what speed each step of his cone or driving pulley on his machine is capable of transmitting, and therefore each pulley should be stamped with the number of revolutions it makes with single, back, or triple gear. By this simple means the operator can start his machine at the proper speed at once for the material he is about to machine. The absence of these helps to the machinist hinders his progress very much and lessens his confidence in himself, especially if he be a stranger to the machine and the work.

Attention should also be given to proper arrangement and management of a tool room from which the tools may be supplied to the men, all ready for use, properly dressed, and to which they may be returned after finishing the job or when requiring regrinding. Much waste of time and material may be caused in a machine shop by workmen running to and from the grindstone, and grinding tools to any angle, usually the one which gives the least trouble. No one except those who have gone into the question of this loss occasioned by each man grinding his own tools would appreciate how much this item alone adds to the price of any article when, for all the time a man is spending at the grindstone he expects to earn a piece-work rate of pay.

The master should not only acquaint the operator with the best speeds and supply the best tools for the work, but he should accurately know the amount of work the tool is capable of doing with the machine running at the speeds given on the plate. The master should also have some easy method of calculating the amount of work the operator is capable of doing, so that his labour in arriving at the correct price may be reduced to a minimum. The easiest way to determine the price, one might say, is to allow the operator to do one piece of work and fix the price accordingly. This may be the easiest, but it is by no means the best for either the employer or the man. Under such conditions the man decides what the price shall be, and the moral power of the master is weakened; the time wasted in watching over a machine while the job is being done is also considerable.

Even if this method of determining the time taken to do work be adopted, it is not one which is calculated to inspire the workman with good feelings towards the master, and, therefore, it should not be followed except in special instances. But the "watch system" is not so bad as the system of "guess."

From the latter trouble invariably arises, and the workman, as a rule, suffers, and often goes unpaid for work honestly done.

The best and simplest method of finding the time taken to complete any piece of work is to ascertain the actual time the machine takes to do each operation, such as turning, boring, parting, facing, drilling, screwing, etc., from the various natures of materials used. Then reduce the time determined to that which is required to do 1″ length on 1″ diameter, so that whatever be the length or diameter of the job, the actual machine time is equal to the diameter in inches multiplied by the length in inches, and by the time taken to do 1″ length on 1″ diameter.

To know the actual time the machine is at work is, however, not all that is required in order to fix a price on any article. Sometimes the hand labour in the preparation of the machine, together with the various movements necessary while doing the work, the setting and adjusting of tools, etc., take more time than the actual machining. It is, therefore, necessary to classify work under different headings, and sum up and tabulate, in order, the separate periods of time actually required to do the different kinds of hand labour for various jobs. In some cases the time is best expressed in a 1″ length, 1″ diameter, and sometimes in a 1″ length on any diameter, or as a fixed amount per article; but by having these times systematically based, an immense amount of time is saved.

In the case of screw-cutting in the ordinary lathe, it is obvious that the time taken to cut a thread 1″ long on 1″ diameter would be much more than the time to cut 1″ length on a 1″ diameter screw 12 or more inches long, simply because in the case of the former the same time is required at the end of each cut to engage the saddle nut with leading screw, as in the case of the screw one foot or several feet long. It is, therefore, necessary to have one table for machine times and one for hand labour times, and when the total time is found from these, from 5 to 10 per cent. should be added to it, according to the amount of hand labour and bodily exertion required and for other necessary allowances.

Such a base of calculation has been found to work satisfactorily. There are difficulties still to be overcome, principally where a miscellaneous class of machines has to be used. It is often the case that the difference which exists between the slowest speeds in the single gear of a lathe headstock and the fastest speed in the back-gear is so great that the number of revolutions which are required cannot be found. This, along with other obstacles to the uniformity of systematic pricing, known by those who have the management of workshops, should be carefully considered when framing the scale of times from which different articles have to be priced.

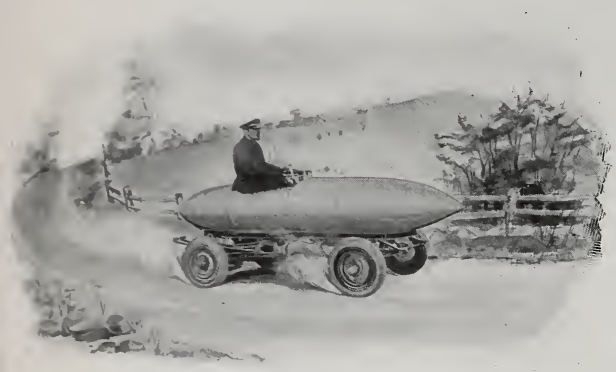
Current Topics

HYDRAULIC power for driving machine tools of the kind with which the conventional machine shop is equipped, lathes, planers, drill presses, and others in which the cutting of metals constitutes the work to be done, is something of which comparatively little is heard, even though the water motor may suggest itself now and then as an engine from which more pretentious work might be expected than that to which it is ordinarily applied and which usually does not go beyond the driving of comparatively small machinery, small ventilating fans, for example, sewing machines, blowers for church organs, ice cream freezers, etc. In at least one instance, however, it has been proposed to equip a number of machine-shop tools each with its own water motor, after the manner now followed so largely in connection with electric driving, and, to that end, to install a hydraulic pipe system from which water under pressure could be supplied to the several tool motors, to be eventually exhausted into a discharge pipe system which would lead back to the pressure pump, through which the water would be circulated over and over again. In point of simplicity and durability such an outfit has been thought to commend itself well, and when to these features are added the attending advantages that such a system would offer fire protection, from the fact that the pipes would afford an ever-ready water supply, and that in cold weather the water could be heated, both to prevent freezing-up of the system and also to serve as a warming medium for the building itself, it would seem as though the scheme might be worth more than passing attention.

APROPOS of the item recently printed in these pages concerning the proposed cooling of magazines of warships by the installation of special refrigerating apparatus, Messrs. J. & E. Hall, Ltd., of London, builders of refrigerating machinery, announce that as long as two years ago they equipped some of the ships of the British Navy with such magazine-cooling plants and have similarly fitted out warships for several of the foreign powers. Evidently, therefore, this particular application of refrigerating machinery is older than has been generally known, and it is interesting to learn that it has successfully gone beyond the experimental stage.

AUTOMOBILE racing is going to be decidedly in fashion this year, especially in France, where a number of notable

races are to be run off during the time of the Paris Exposition. The distances to be covered will range as high as 342 miles,—the stretch between Paris and Bordeaux,—and the vehicles, it is safe to predict, will be a sufficiently variegated collection to satisfy every one. What may be expected during this time



SIXTY MILES AN HOUR BY AUTOMOBILE.

is, indeed, indicated to some extent by the announcement that one of the contests is to be held on a wager of the Baron de Caters and M. Jenatzy, the builder of the "projectalite" racing machines, of which the annexed sketch has been redrawn from *The Automobile Magazine*. Both of these, so it has been stated, propose driving automobiles capable of covering about 60 miles an hour, and at this rate some interesting things may be learned as to motor carriage high-speed possibilities.

THERE is probably not a steam user anywhere who has not been told at different times of the notable economies that he might effect if he would only adopt the particular devices that his informants had for sale. For all these there is a special interest in the story which Norman Selfe tells in his just published book on "Machinery for Refrigeration," of the man who adopted all the latest improvements offered to him, and who, when he had paid all his bills and summed up what had been promised him, obtained the following as the gross saving to be expected:—By contorted tubular boiler, 20 per cent.; acrobatic fire bars, 10 per cent.; steam dryer, 5 per cent.; automatic damper regulator, 5 per cent.; patent cut-off, 15 per cent.; waterless condenser, 20 per cent.; economiser and feed heater, 25 per cent.; purifier and softener, 10 per cent.; making altogether a saving of 110 per cent. He, therefore, concluded that he should be burning 10 per cent. less fuel than nothing, and that his coal heap should be getting larger instead of smaller; but, somehow or other, he found that the coal went away just about the same as before.

THE statement was recently made that the great defect of all machine firing for steam boiler furnaces was that it did not lend itself to changes in the rate of firing; that, in fact, it was this very inflexibility that was also its virtue, insuring, as it did, equable evaporation and proper combustion; and that where boilers had to be forced for an hour or two, as in electric light stations, to carry the peak of the load, hand firing had been, so far, found indispensable. All this, however, requires some qualification. There are various systems of machine firing. Some do and some do not admit of forced service in emergencies, and it is not quite in accordance with the facts to make the above statement all-comprehensive. Mechanical stokers have undergone much improvement in the past half dozen years, and the best of those now on sale by different makers have given excellent results under all kinds of conditions and in all kinds of service.

IN discussing the growth of monopolies in one of the admirable little sermons which Thomas Hitchcock periodically contributes to the financial columns of the New York *Sun*, he pointed out recently that simultaneously with the progress toward corporate monopoly of the capital invested in industrial undertakings a corresponding movement to-

ward a universal alliance for aggression as well as for defence is observable among the labourers on whom that capital depends for the means of making itself productive. The labour unions, originally formed only to secure for their members the wages and the treatment to which they believed themselves entitled, have, within a few years, developed into organisations for preventing the employment of the labour of others than those who belong to them. Ostensibly, they exclude none from membership, but, practically, they restrict admission to it as much as they dare. The means employed to further their ends by the monopolists, both of the machinery of industry and of the labour engaged in working it, are such as a knowledge of human nature would lead us to expect. The capitalists are, indeed, more refined and ingenious in their proceedings than the labourers are, but, while they offer no personal violence to those who resist them, they make, in ways which are unjust if not criminal, opposition to them costly and dangerous. The labourers, on their part, less scrupulous to observe legal forms, enforce their demands with clubs, pistols, knives, and, latterly, with a boycotting, which, like the ecclesiastical excommunication of the Dark Ages, makes the life of its victims unendurably miserable. Both parties, however, are animated by the same spirit, both aim at monopoly, and both seek to extinguish the competition which interferes with the attainment of it.

This struggle of monopoly against competition goes back earlier, too, than the beginning of industrial, social, religious and political history. It lies in the constitution of the inanimate as well as the animate world. Between centripetal and centrifugal forces the planets move in their orbits round the sun. In the conflict of physical and chemical attractions and repulsions are born the various kinds of vegetable and animal life. The fishes of the sea, the birds of the air and the beasts of the earth live either by exterminating fishes, birds, and beasts of less strength than their own, or upon plants, which, in turn, are at constant war with one another, every species invading the domain of some other species, as any of us who have tried to cultivate the soil can testify. These things being so, it is evidently futile to endeavour by legislation to arrest the prevailing tendency toward the acquisition by aggregated capital of monopolies of industrial enterprises. The process must go on until it develops evils to society against which society will take measures to protect itself as it does against other evils which injuriously affect its welfare. Merely to enact that capital shall not be aggregated beyond certain limits, would, of itself, do more harm than good. We might as well, for fear of the tyranny of churches and labour unions, enact that they shall consist of only a fixed number of members and no more, that cities and counties shall contain only a limited number of inhabitants, and that lawyers shall not get as many clients, and doctors as many patients as they can.

Short of the extreme measure of confiscation, to which resort can always be had in case of necessity, the natural effect of the competition which monopolies aim to suppress can almost always be relied on to counteract any abuse of monopolistic power. If the commodity furnished, like water, for example, be of indispensable necessity and limited in supply, then, indeed, competition is powerless against monopoly, and the sovereign right of the people may have to be exercised. Or, if all the avenues of travel and transportation fall into the hands of a single owner, a like remedy may have to be employed to protect the public from extortion. In most cases, however, absolute monopoly is impossible from the nature of the case. In the refining of sugar in the United States, for example, it has been shown that no matter how rich and powerful may be the corporation that endeavours to control it, new and equally rich and power-

ful corporations will spring up to contest its supremacy, and by the war the public gains.

THE attempted monopoly by labour unions of the supply of labour is subject to a similar check. The effect of forcing wages above the level at which they would stand with competition free to the whole world is to attract labourers from other lands. In the United States the Chinese have been shut out, the importation of labourers under contract has been prohibited, and yet every week steamers bring thousands of immigrants, whom no law that can be made, short of the absolute exclusion from the country of all foreign-born persons, can stop from going there and seeking employment at the high remuneration offered them. Generally speaking, there is no reason to be so greatly alarmed at the progress monopoly is at present making, as some politicians and newspaper writers profess to be. In fact, the outcry against the gigantic corporations which have latterly come into existence is due rather to envy of their supposed profitableness than to a real conviction that they are a menace to the country's welfare. Shares in them, it is observable, find plenty of purchasers, and the dividends paid by them are pocketed without compunction. So long as this demand for participation in the earnings of monopolies continues, opportunities for gratifying it will be multiplied, and this, whether the monopolies be those of the products of labour or those of labour itself.

WITH the fever of trades unionism now rampant, it is particularly interesting to learn that in one locality at least the labour agitator is not in favour with wage-earners and State protection has been asked for by them against his coercive efforts. This unusual situation recently arose at Indianapolis, Ind., U. S. A., where the tramway employees refused to continue the union which they had formed a short time previously. After they had been organised they alleged that they had been misled, and by a practically unanimous vote the union was dissolved and the charter was returned to the national organisation. At this point the Central Labour Union, with which the Street Car Union was to be affiliated, stepped in and affirmed that the men had been coerced into surrendering the charter. This was denied by the employees, who again declared that they had been deceived, and that, instead of having formed a benevolent organisation, they had formed a labour union, a thing which was not necessary to them. The Central Labour Union nevertheless insisted upon proceeding against the street car management, and began to bring pressure to bear upon the employees to force them into a strike. Subsequently a committee from the employees waited upon the State Labour Commissioner and informed him that the Central Labour Union was fomenting trouble among them; that they did not want to form a union; and that they are satisfied with their wages and with the hours they work, and they asked him to interfere as a State officer in their behalf. They added that it was the purpose of the Central Labour Union to bring about a strike in order that a union might result from it, and not having any grievances, they appealed to the State authorities through the Commissioner to prevent the agitation and to protect them from its consequences. The whole transaction furnished an interesting exposition of trades union meddlesomeness, and it was a significant circumstance that the men themselves in this instance appealed for protection against the union agitators, the self-styled "friends of labour."

PHOTO BY DAVIS & SANFORD NEW YORK

E. D. Meier

SEE PAGE 174

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TRADE POSSIBILITIES IN SOUTH AFRICA

By Edgar Mels

WITH a most energetic present on its hands, South Africa is thinking little of its future, despite the fact that such future promises much for the Land of Good Hope. A land at war is too busy to pay much attention to speculation as to what the future may contain, but this does not alter the fact that, unless the past be no criterion, the years to come will prove South Africa to be a modern Golconda for both the miner and the merchant.

Much has been written, but little elucidated, of the racial differences alleged to exist between the Boers and the so-called Uitlanders. The Boer does hate and despise the speculator and the "financier," whom he blames, perhaps with justness, for the present war. The real Englishman, who went to South Africa to make an honest living by hard work, has been, and will be, welcomed by the Boer and his cousin, the Afrikander, as a brother. Indeed, the Briton and the men of Dutch extraction and sympathies lived side by side for years in the utmost friendliness. It was only when politics became rampant that trouble arose. After the war shall be a thing of history the men who fought bravely against one another will fraternise for the good of the land, be they Briton or Boer.

The mere mention of the name South Africa brings visions of gold mines and of diamonds, but neither is as apt to bring prosperity to the land as is commerce,—the possibility of tremendous manufacturing and import business. In this lies the probability of a prosperous

NATIVES BOUND FOR THE GOLD FIELDS

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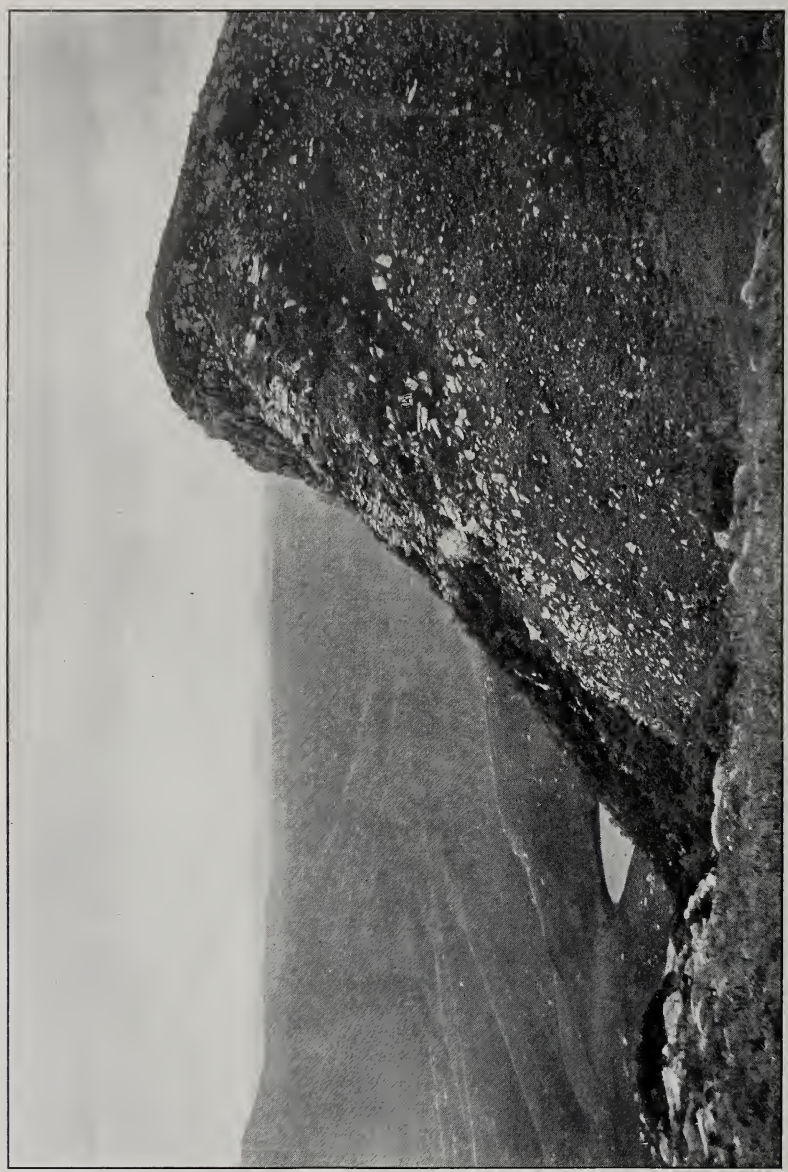

FROM THE SUMMIT OF MAJUBA HILL

future. Diamonds and gold and other metals and minerals, to be found in profusion in South Africa, will prove a mere incident in the history of the country. Trade, based upon the solid foundation of manufacturing interests and of agriculture, will prove the salvation, commercially speaking, of South Africa.

Before diamonds, and subsequently gold, were discovered, the land was on a far better basis than it was just before the present war began. Prior to 1869, when diamonds were first found in Griqualand West, near the Vaal River, was sufficient to fill the most extensive larder. It is true that business was embryonic, but the country prospered, nevertheless. Speculators, perhaps, will declare that the discovery of diamonds alone saved the Cape Colony from bankruptcy; but mines, unless supported by industries and agriculture, are apt to be a curse, instead of a financial blessing. Indeed, the mines of South Africa have proven a curse. Their very existence and conversion into stock companies caused excitement in all quarters. The famed South Sea

THE MAJUBA BATTLEFIELD

South Africa was famed for its wool and its wines. Millions of sheep and cattle grazed in undisturbed solitude over the rolling veldt where bloody battles have since been fought. Down on the slopes in the southern part of the Cape Colony thousands of acres were given over to grape-raising. Even now vineyards form the mainstay of the colony's best prosperity.

The farmer prospered then and ruled supreme. The country was distinctively pastoral, with few wants, but those wants easily and well supplied. Cereals and foodstuffs sufficient to supply the demand were easily raised. Meat was to be had for the asking, for game was still plentiful, and an hour's shooting

Bubble caused no wilder and less sensible speculation. Men, sane under ordinary conditions, went mad with the fever of speculation. Common sense, business acumen, and even honesty were discarded and the mad race for money began. Some stocks rose from next to nothing to almost fabulous figures, even though worthless as genuine investments. Eventually the bottom fell out and thousands were ruined.

All the while legitimate business was practically at a standstill; commercy was neglected, and the entire countre suffered. Then the population, because of the need of daily bread, turned again to legitimate pursuits and renewed prosperity came to the land. Scarcely, how-

ever, had the country recovered from the first shock when the speculative fever took a new hold, with the same unfortunate result.

As long as the individual was a factor in diamond mining Kimberley grew and prospered; when the mines were consolidated, it fell into a lethargic state, which was deepened by the discovery of gold in the Witwatersrand district. While the individual could dig for gold in his primitive way on the Bezuidenhout farm (on which Johannesburg now stands) prosperity reigned. The moment the various claims were amalgamated dull times came, and while the few made money, the vast majority suffered.

This is not a diatribe against trusts or mines, but an argument to support the writer's contention that the future of South Africa lies in trade and agriculture. In order to make this more clear it will be necessary to delve a little into history.

To begin at the beginning, South Africa has been called the Land of Ophir of the Bible, but this it can scarcely be said to be, for all of the African continent south of the Zambesi River is of too recent volcanic origin. This is proven by the Kimberley mines, all of which are the extinct craters of volcanoes. Then, too, all through the country, from Table Bay in the south, to the Zoutpansberg in the north, can be found sea shells,—evidence that the land was once submerged. At Bloemfontein there is, or was, an exhibit of fossilised fish found in various parts of the Orange Free State.

THE "RAAD ZAAL" OR TOWN HALL AT BLOEMFONTEIN

Ancient relations with South Africa date back to 600 B. C., when an Egyptian fleet, despatched by Necho and manned by Phœnicians, sailed south through the Red Sea, and returned, two years later, through the Pillars of Hercules. The first vessel of really modern date was Portuguese, and was captained by one Bartholomew Diaz. He sailed from Lisbon in 1486, and on sighting the Cape of Good Hope called

BLOEMFONTEIN, THE ORANGE FREE STATE CAPITAL, SEEN FROM THE NORTH

it Cabo Tormentoso, the Cape of Storms.

The next step is to the early part of this century, when Great Britain obtained possession of the Cape Colony from Holland. At that time the white population was limited and scattered over a large area, although naturally it was densest near the coast. Trade was merely nominal, and nearly all the necessaries of life had to be imported. Labour was cheap, for slavery was still legal, and the settlers were content to live from hand to mouth. Aside from the annual Kaffir wars, nothing of consequence took place until 1834, when slavery was abolished, the British government paying the owners of slaves for their loss. There was, however, much discontent over the price paid, and especially among the Boers. In consequence, the great trek was organised and several thousand Boers crossed the Orange River to where Kronstad is now located.

This changed the entire history of the country and incidentally the trade conditions, for, being so far from the coast, the trekkers were forced to raise their own products and to take still more to agriculture. Thus began the first demand for agricultural implements and for arms and ammunition. Clothing, too, and other necessaries had to be imported, for manufacturing was still an undeveloped factor in the Cape Colony.

More Kaffir wars followed, with the continuous acquisition of territory on the part of the whites; immigration began, and South Africa assumed the aspect of a miniature world power. Then diamonds were discovered in Griqualand West, and also in a part of the Orange Free State. This of itself was of minor consequence, but the find brought a rush of human beings from all quarters of the globe. Business of all kinds improved and prospects seemed bright, when financial geniuses, with probably the best of intentions, consolidated the thousands of mining claims and formed what was subsequently called the De Beers Consolidated Mining Company. While it is true that the De Beers have paid from 5 to 20 per cent. dividends a month, it is equally true that the consolidation, in a measure, killed Kimberley.

The next step was the discovery of gold, in 1886, on a farm belonging to a Boer named Bezuidenhout, situated thirty-five miles southwest from Pretoria, as the crow flies, and five miles further by railway. The discouraged prospectors and miners from Kimberley took renewed courage and soon Johannesburg rose, phœnix-like, from the

TABLE MOUNTAIN, FROM RONDEBOSCH

memory of the Boer farm. Contemporaneous history declares that the Witwatersrand (Edge of the White Waters) mines are the richest quartz mines in the world. This is borne out by the fact that from 1887 to 1898, inclusive, these mines produced gold worth over £76,000,000.

Despite this magnificent showing, however, and despite the other districts in which the gold is almost as plentful, the future of South Africa is not in its mines. And yet the writer almost hesitates to make this assertion,

THE GOVERNMENT BUILDINGS AT PRETORIA

for wherever you may look in South Africa you will find some mineral in paying quantities. Silver, almost pure, can be found within a stone's throw of President Kruger's house in Pretoria. From Port Elizabeth in the south, to Zeerust in the north, silver exsits. Coal is found in abundance in the Cape Colony, in the Stormberg district; in Natal, near Dundee; in the Orange Free State, at Bethulie, and near Kronstad; in Zululand, near St. Lucia Bay; in the Transvaal, near Klerksdorp; at Boksburg, near Johannesburg, and in many other parts of the country. Copper deposits of great value have been mined for fifty years in Namaqualand; new ones have been discovered on the banks of the Limpopo River, and in the Murchison range, in the Transvaal. Lead, plumbago, zinc, antimony and tin are found in paying quantities in the Malani district and in Swazieland. Iron, too, is common. Asbestos is being mined near the Orange River; mica exists in the Zoutpansberg. Salt is plentiful at Uitenhage, in the Cape Colony, near Craddock and Bloemfontein. Sulphur is being mined near Malmesbury, near Amsterdam, in the Transvaal, and east of Tuli, in Rhodesia. Mineral oils have been located in Natal. Nitrate deposits have been found in the Doornberg Mountains, near Priska; saltpetre near Bethlehem, in the Orange Free State. Platinum, bismuth, uranium, strontium sulphate, barium sulphate, gypsum, nickel, magnesia and manganese also are found. Among the precious stones found, aside from diamonds, are tourmaline, agate, amethyst, olivine, beryl, opal, carnelian, sapphire, garnet, turquoise, onyx, and topaz. That all this

JAMESON'S BATTLEFIELD

A VIEW OF THE SOUTH AFRICAN VELDT

mineral wealth will be put to use is certain. But it will be the financier who will profit, not the great mass of the people. The latter must look to manufacturing for monetary advantage. At present this has been sadly neglected. Nearly everything needed, from a stamp mill to a toothbrush, has to be imported. The principal industry of the Cape Colony is the manufacture of waggons. The colony has nearly five hundred establishments devoted to this, employing about three thousand hands. Next in importance come the shoemakers, who number about one hundred, utilising the services of about six hundred

men. Another thousand are employed in brewing beer at Capetown, Pietermaritzburg, and Johannesburg. There are also a couple of dozen distilleries. Other industries are:—Iron foundries, 74, with 600 hands; shipbuilders, 9, with 100 hands; furniture makers, 43, with 375 hands; builders and carpenters, 150, with 2000 hands; manufacturing chemists, 50, with 1000 hands; tailors, 110, with 875 hands; bread, biscuit, and candy makers, 125, with 1000 hands; ice manufacturers, 60, with 400 hands; soap and candle works, 11, with 89 hands; coopers, 17, with 199 hands; brickyards and potteries, 67, with 897 hands; and jewelers, 17, with 77 hands.

In Natal there were, prior to the outbreak of hostilities, 42 sugar mills; 11 distilleries; 67 grist mills; 17 saw mills; 19 brick works; 19 waggon makers; 5 tanneries; 2 iron foundries; 3 lime works; 2 tile factories, and one bacon-curing factory.

Agriculture has been the mainstay of the great mass of the inhabitants of South Africa. Travel where you will, as far as the eye can reach stretch farms of more or less fertility, over miles of undulating veldt, in rolling waves of earth, to where the sky and earth meet. Seemingly endless are these farms; thirty thousand acres are considered a medium-sized plot. Of course, the greater part of this land is utilised for pasture, for cattle-raising is a profitable occupation. Sheep and cattle thrive on the scanty vegetation of the veldt, the diminutive karoo-bush furnishing nutriment for millions of them. The karoo is found only in South Africa. It resembles a stunted oak tree, eight to ten inches high, and contains nourishment even after it has been burnt dry by the tremendous heat of a merciless sun. The best pasture land is to be found in Mashonaland and in Matabeleland, although that part of the Transvaal where rooi-ground (red ground) is to be found is favourable also for cattle raising.

The solution of the agricultural problem is in irrigation, for the soil of South Africa is very rich, similar to that of the Nile valley. Cereals can be grown in any part of the country where water is obtainable, and especially in that part of the Orange Free State known as the Conquered Territory, which is the granary of that part of the world. As high as forty bushels of wheat have been raised there on one acre.

If the vast tracts of veldt, hitherto

AFTER A KAFFIR FIGHT

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THE EXCHANGE BUILDINGS AT JOHANNESBURG

THE HOUSE OF PARLIAMENT AT PIETERMARITZBURG, NATAL

barren because of the uncertain rainfall, be irrigated, the world will be astonished. Even the Boers have realised this, and some time ago began a rather primitive system of irrigation, utilising, at the same time, the advantages accruing from the use of American agricultural machinery.

So, when peace shall again reign in the land of minerals, the Land of Good Hope, but, so far, of poor results, the manufacturer and merchant will reap rich profits. No matter which side will win in the present struggle, the Boer, the Afrikander, and the Uitlander will all require clothing, and foodstuffs, and agricultural implements, and mining machinery, and other necessaries. Peace will bring with it thousands of new settlers, with all their needs. Trade will be sitmulated, and the merchant, whether he sell shoes or steam engines, will be the gainer.

There is the possibility that so soon as the British shall be in sight of Johannesburg, the Boers will wreak vengeance upon the mines. Then the manufacturer of stamps, and engines, and pumps, and other machinery will have to replace the damage done. The town itself may have to be rebuilt. But—and that "but" is all-important—but, trade must be conducted on a different basis than hitherto. There must be no more misrepresentation, no more misleading statements. The manufacturer must be able to rely upon reports,—hitherto he has been deluded with the rosiest tales, only to discover eventually that, in his instance, truth lived in a very deep well.

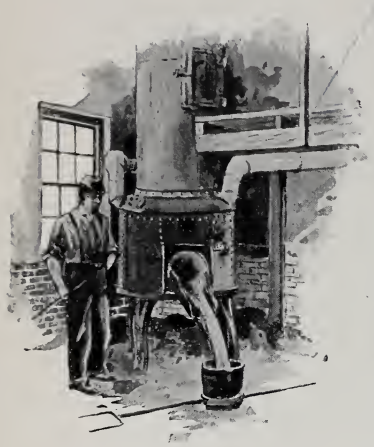
Then, too, the politician and the financier must keep their hands off. Both have wrought more ruin than they can ever repair. Both have been the agent of a certain style of development, in the end detrimental to the country. Now that they have had their opportunity, the man of business should have his.

Let the latter direct the future of South Africa! Let him direct not merely the business of the country, but its government as well, and South Africa will prove a worthy rival in every way to larger and to-day more prosperous nations.

The future of South Africa is now a mere question of business. Which will it be,—business or politics?

THREE SYSTEMS OF SELLING PIG IRON

By George H. Hull



IRON is so thoroughly the basis of all industries that what affects it must affect all manufacturing business. The question, therefore, which most concerns every consumer of pig iron is what system will insure the greatest regularity in supply with most stability in price?

An ideal system to fit such conditions would be the existence of some group of charitable individuals, with vast wealth, who would come forward and buy from the producers, for cash, at fair prices, all the surplus iron made during the several years of small consumption, and then, in turn, during the recurring seasons of great manufacturing activity, resell it to the consumers.

Which system most nearly resembles this ideal will, perhaps, become apparent from the following account of the methods of conducting the pig iron business in the three most important iron-producing countries,—Great Britain, Germany, and the United States,—originally presented by the writer in a paper recently read before the Associated Foundrymen's Association.

THE GERMAN SYNDICATE SYSTEM

The pig iron business of Germany is conducted by a syndicate or association of the individual producers. The leading idea of its organisers was to do away with needless and ruinous competition among themselves. At the time of its formation it was made quite clear that the organisation did not wish, or intend, to enhance prices to the consumers in an oppressive way.

At the beginning each member was required to file a statement of his or their production for a number of years, and the average annual production of each, as thus shown, was made the basis of the percentage of production allowed to each company from time to time. When the demand for iron falls off, the total production of the furnaces is cut down accordingly; when the demand increases, the total production, as far as the capacity of the furnaces permits, is increased to conform to the greater demand. As it is not always practical for each company to cut down production to meet the arbitrary percentage ordered, the difficulty is met by a payment, by the syndicate, to the furnace company which makes less than its allotment and by a corresponding collection from the furnace company which makes more than its allotment.

In order to keep the respective parties to their agreements, each individual or company, on being admitted to membership, is required to deposit with the syndicate bank, an accepted sight bill for a certain amount, with the condition that said sight bill is to be forfeited to the syndicate if the conditions of the agreement are violated by the member depositing it. The syndicate has one office. All inquiries for iron from consumers and dealers must be addressed to this office, and no member is allowed to sell except through this channel. The syndicate purchases all supplies for its members; it fixes the prices for the different qualities of iron from time to time; and it will sell for delivery six or twelve months ahead, or longer, to meet special requirements.

The system has resulted in a large reduction in the expense of selling iron,

and in a very considerable saving in the purchasing of supplies. It has entirely done away with ruinous competition, and has maintained prices which have been fairly remunerative to the producers.

There are objections to the system. It puts all the power in the hands of the producers, a power which is at any time liable to be abused. It is artificial. It is not the result of free and untrammeled operation of natural laws. It is a forced condition, held together by an agreement which is maintained by the fear of forfeits and penalties. History does not furnish a single example of any business system, formed and maintained by such methods, which has endured. The serious defect of the system lies in the fact that it not only lacks a method of accumulating and carrying a reserve stock in dull times, but its chief object is to prevent such an accumulation. A system which restricts the production of the article most necessary to the growth of the country in wealth and power is arrayed against the public good and should be prohibited by national law.

THE BRITISH WARRANT SYSTEM

The British warrant system originated in Scotland about the year 1840, though no statistics of it have been preserved further back than 1845.

The functions of a warrant company are few and simple; it receives into its yards, pig iron which it has previously weighed, inspected and classified, and for which it gives to the owner of the iron a warrant. This warrant is simply a negotiable warehouse receipt which describes the brand, quality and weight of the iron it represents, and gurantees or warrants that on return of the warrant duly indorsed and payment of storage it will deliver the iron it describes, free on board cars, to the party presenting the document.

A warrant company performs no other acts or functions, but the effect of these acts is to create a document which the furnace company can sell for cash and which can be transferred by sale any number of times, each purchaser becoming the owner of the iron by the transfer of the document, each purchaser having the right to resell the warrant or to cancel it and obtain the iron for export, consumption or any other desired purpose.

At first the Scotch warrant consisted of scrip or storage receipts, issued by the pig iron makers, for the convenience of dealers; but so many irregularities occurred that it was found necessary to have the iron stored in the yards of an independent firm of undoubted standing. The firm of Connal & Co., now Connal & Co., Limited, of Glasgow, inaugurated the system of issuing the present "Storekeeper's Warrant."

For fifty years these warrants have been regarded as an absolute security; money is loaned upon them with confidence by every bank in the kingdom, the prevailing rate of interest being one-half of 1 per cent. per annum above the Bank of England rates, which is a rate enjoyed only by the most favoured collateral. The semi-daily dealings in these warrants is the prominent feature on the floor of the Royal Exchange of Glasgow. The warrants are bought and sold not only by the iron producer, consumer and merchant, but by the general public; it is, in fact, the favourite security among all classes who buy and sell for a profit, and the dealings, in consequence, are enormous; there are more than seventy members of the exchange who make a specialty of buying and selling warrants for the public.

The statistics of the Scotch warrant system show that the average reserve stock of iron carried by that method during the last fifty years has been more than six months' production; for one period of five years it was more than twelve months' production. There have been six periods of accumulation and six periods of depletion of stock, and three times these large reserve stocks have been reduced to less than 100,000 tons. This is evidence that the seasons of accumulation were not seasons of over-production, since each accumulation was afterward almost entirely exhausted by the legitimate business demands of the country.

It is no more over-production to make and store up enough iron in seven years of dullness to supply the business of the country through two years of activity, than it is to raise and store up in a few weeks of harvest enough grain to supply the country during twelve months of consumption; it simply requires a broader mind to take in the proposition.

Great Britain has been the country to which for a century all the world has looked for everything connected with iron. A British contractor will undertake a contract in a foreign country which requires 50,000 tons of iron and five years to complete as readily as an American contractor will take one which can be completed in a few months, simply because he can protect himself against fluctuations in price of iron and steel through the warrant system. When a contract is taken by the British contractor he immediately closes a contract with his exchange dealer for warrants covering 50,000 tons at the market price, which the dealer agrees to carry at a penny per ton per month storage and a low rate of interest, perhaps 1½ per cent. per annum. It may be a year before the contractor is ready to give an order for the first 10,000 tons of steel to be used in his work; when he gives the order he sells an equal tonnage of his warrants. If the price of steel has advanced, the warrant iron has advanced; if iron has declined, he buys his steel at a corresponding decline; he is thus protected on each order he places for steel during the five years. By this means he eliminates all risk of fluctuations and confines his business to its legitimate profits.

The warrant system has no disadvantages, and no just argument can be made against it. There is no good thing, however, which cannot be misused. Some people have tried to "corner" the warrant market, and, as usual, been badly crippled in the attempt. These victims of their own folly have made an outcry against it and made an effort to have the system abolished by Parliament. They were like the few frogs in the pond which made so much noise that it was thought there were a million, but when the round-up took place they discovered the three loneliest men who ever arrayed themselves against a nation. It would be just as reasonable to ask Parliament to abolish razors, because a few people have been known to cut their throats with them. The effect of these "corners" upon those who were engaged in the legitimate business of producing, consuming or dealing was simply to give them an opportunity of unloading all their surplus on the speculators at high prices while the "corner" lasted, to be bought back the next month at a handsome profit. The legitimate price of a staple must, and always will, assert itself by and through the actual business doing in that staple. Speculative interference has had, and can have, only a temporary influence.

An argument used against the system by some of its opponents is that it creates a collateral on which producers can easily borrow money from banks, and that parties have sometimes so borrowed and have increased and continued so borrowing on their product until they were ruined.

This argument is characterised by such intellectual depth and penetration that the only remedy to be suggested is that Parliament be asked to abolish banks at the same time it does razors. It is, of course, a folly for any producer to pile up his product and carry it for several years with interest and storage charges accumulating against it, for, unless it advances enormously at the end, it is likely to terminate disastrously. The dealer, however, under modern exchange methods may carry iron under these conditions and make a handsome annual profit in so doing.

The opinions of prominent men in England and Scotland who have been identified with the iron business for a generation can be summarised as follows:—The warrant system works beneficially in every respect to both the producer and consumer. Through it the maker, even in dull times, finds a ready market for that portion of his product which is not taken promptly by the consumer or dealer. Through it the consumer is brought, in effect, face to face

with every seller, be he producer, dealer or investor, and is thus able to buy to the best possible advantage. The producer who anticipates a decline may sell his product for months or years ahead, take out warrants for it as made and collect cash for his warrants as presented. The consumer, if he anticipates an advance, may provide for his requirements for months or years ahead with certainty that the iron will be delivered to him immediately on presentation of his warrant. It has all the advantages of the syndicate system without its disadvantages, and, at the same time, allows free scope to individual opinion and enterprise. It is, in fact, a balance wheel to the whole trade.

The system is not forced or artificial. It is of natural growth, built up by the free and untrammeled working of all the elements through an experience of centuries. Neither party controls it. It does not tie the hands of any element. It is not maintained by any agreements which must be held together by forfeits and penalties. It has nurtured a body of strong, vigorous, self-sustaining producers and consumers. Its existence and growth have depended on its usefulness to the producer and consumer alike, and its continued existence for sixty years without change, while constant changes have taken place in the systems of other countries, is the best evidence that it meets the requirements of all the interests connected with the iron business. Above all, it is an effective means, and the only means, through which large reserve stocks can be accumulated without depressing prices. It is, in short, a working-out, on sound and natural business principles, of the ideal system pictured in the opening of this paper.

AMERICAN METHODS OF SELLING IRON

The pig iron business of the United States has been of such sudden growth that it has not had time to crystallise into a system. The methods of to-day are simply what changing conditions and necessities have made them. In 1840 the total production was but 290,000 tons; at that time the iron was sold by furnace companies. Twenty years later it had increased only to 820,000 tons, and was still sold largely by the producer; but in the interim, through various causes, such as needy producers being obliged in dull times to pledge their iron for advances in money or supplies, the trade in the large cities had drifted partly into the hands of wholesale dealers in merchandise. The iron so pledged was first shipped from the furnace to the merchant, who hauled it to yard and stored it, which necessitated a second hauling and shipment when it was finally sold to the consumers. This double handling added greatly to the expense, and the merchant having other business gave only incidental attention to selling iron. The selling business, being only half done, was poorly done.

Later on the merchant's portion of the business went over to commission men, in consequence of the latter being able to give their whole attention to selling; but it was not until the commission agents abandoned the system of double handling, and inaugurated the system of making sales, to be filled by shipment directly from the furnace to the consumer, that the makers gave up selling it themselves and turned the business over entirely to the commission agents. When this method became general, the makers had agents in each important distributing centre, and confined these agents to the territory most easily reached from such centre. The number of agents was small, and each one represented several different brands. Under this method the competition was greatly reduced, and was much less destructive to profits than when the makers sold part of their own output. There were at this period about 600 producers, and yet the competition was confined to from two to half a dozen agents in each territory.

Later on, when the agents became stronger financially and were able to aid their principals, these stronger concerns secured exclusive agencies, with authority to sell in all territories. This increased the competition greatly, as each territory was invaded by the agents from

several other territories; the agents were compelled to employ many travelling salesmen in order to cover the larger fields, and thus their own expenses were increased to such a degree that their business yielded but little profit. This has resulted in the agents taking on other staples, such as coal, coke and the manufactured products of iron and steel, and, more recently, in becoming buyers and sellers on their own account, as well as becoming interested as producers. In some important markets, like Pittsburgh, the iron commission agents have already disappeared and been replaced by the dealers.

By these changes the American methods are gradually approaching the British system, under which the iron is handled principally by dealers, and it is a notable fact that the largest increase in business among iron sellers in the United States has been with those who have been the largest buyers of warrants and iron on their own account, the fact of having something of their own on which they could make instant quotation giving them a great advantage over those who must consult a principal. A business must have some independence to insure its growth and permanence; the commission iron business, which is necessarily dependent on both buyers and sellers, has no independence and is always hampered.

During all these changes in the American methods many efforts have been made to form associations in the United States, similar to the German syndicate system, but what has been practical in a country of 212,000 square miles, where the interests of all producers were similar, has been impossible in a country of 3,600,000 square miles, where the interests of the producers were so conflicting and varied. At the present time such associations or syndicates are prohibited by United States law.

Thus for sixty years, through constant changes, the American producer has been struggling for some satisfactory method of marketing his product, and if, during those sixty years, there has been one producer or one consumer who has been satisfied with the methods in vogue, he has failed to make himself known to the world. We hear of furnace companies building works to consume their product, because they cannot sell it to advantage, and we hear of consumers building furnaces to make their pig iron, because they cannot buy it to advantage; but we hear of no one who is satisfied with conditions as they are. The methods in vogue have given to the American iron business only the experience of constant suffering, seven years when the makers are suffering for buyers, and two years when the consumers are suffering for sellers. During all this time the iron business of Great Britain has been conducted under one system, and the writer has never encountered one who did not consider the British system a benefit to both producers and consumers.

Next to a good government there is nothing so important to the business welfare of any progressive nation as an ample supply of iron and stability in its price. Any condition which causes an advance of 100 per cent. in the price of any important staple is an evil; such an advance in the price of pig iron, the staple on which the country most depends for its growth in wealth and power, is a calamity. All other things advance in sympathy until they reach a figure which every thinking man knows cannot last; the greater the advance, the greater must be the decline, and the more disastrous must be the depression which follows. Does any one believe that the advances in all commodities would have reached the present enormous figures if the advances in iron during the last twelve months had been confined to 10 or 15 per cent.? Keep the price of iron within reasonable bounds and you keep everything within bounds! Let us have investors, dealers and speculators to buy the surplus in dull times and it will rarely, if ever, go as low as cost again. Let us have the reserve stock which these added elements will accumulate to supply us in active times and it will never again go up to such enormous figures.

The principal argument used against the adoption of the warrant system by

its opponents in the United States is that the introduction of speculation into the iron business will increase the fluctuations in its price, and yet statistics show that directly the opposite effect has attended the introduction of all other articles to exchange dealings in the United States.

With the great advantages afforded by the British system, and the disadvantages caused by the American want of system, it may seem strange that the warrant system was not adopted in the United States forty years ago; but every business, like every individual, must go through a period of development, and this takes time and experience. It is no more possible for a small or new business to adopt mature methods of administration than it is for a youth to assume the mature manners of the adult.

The iron business of Great Britain is several hundred years old; it was a strong, vigorous adult when the iron business of America was a puny infant. The methods in vogue for the last fifty years in the iron business of America had been tried and were discarded by Great Britain more than half a century ago. The exchange system is simply the final refuge of each business as it expands and discards old and inadequate methods. It is, in effect, simply creating a negotiable paper representative of the article to be dealt in and then bringing, at a given time and place, every one who wishes to buy face to face with every one who wishes to sell that article. Human ingenuity has not yet discovered a method more nearly perfect for controlling a business of great magnitude.

Every business which reaches great magnitude necessarily comes to the warehouse and exchange system. It is the only method which has stood the test of time and which is surely adopted after all other experiments have failed and been abandoned. The plan of accumulating stocks in time of plenty, instead of slaughtering them, has been taken advantage of by dealers in almost everything except pig iron. Only a few years ago there were seasons when the receipts of fruit in the city of New York were sometimes so great within a few days, and the prices were forced so low, that the fruit hardly brought the amount of freight; this, in turn, discouraged shipments, and then would succeed a season of great scarcity. It took experience and many years of loss to rectify this condition, but finally it resulted in the establishment of fruit exchanges and storage warehouses, where fruits were kept at a temperature just above the freezing point, where chemical change ceased, and thus it was preserved in a perfect condition for months. The result is that prices are now more stable, the public is better served, and the profits of both producers and dealers are more uniform and remunerative. Thus, after many generations of waste, a fruit system has been finally developed in the United States. It does not limit production of fruit, and no matter how much arrives in a short time, only what the market will naturally take is offered, and the remainder goes to build up a reserve supply. So we find vegetables, eggs, butter, fish and poultry, as well as grain, cotton, provisions, coffee and many other articles, getting the benefit of a system, while iron is still left to drift in a haphazard way.

The American warrant system has made a small beginning, but it has demonstrated the fact that it constantly absorbs surplus iron during the dull periods and steadily gives up this stock when the country most needs it.

But warrant yards are only part of the warrant system; to make it complete, there must be daily exchange dealings of such magnitude that buying and selling orders can always be promptly executed. The system has been a benefit to those who have given it a fair trial. It has in many instances been the only channel through which needy furnace companies have been able to get money in times of great stringency, and has saved them from being obliged to blow out or bank their furnaces.

The reserve stock accumulated by this system, although small, has furnished the iron to tide over many a manufacturing concern during the last

year, which, without it, must have suspended work at times when it would have caused them loss and great inconvenience. It has been of the most pronounced benefit to such dealers as were the first to take hold of it. The growth of their business has been almost in exact proportion as they have dealt in warrants, not only in the domestic, but in the export business. In fact, no one appears to have made a success in the export business except those who have dealt in warrants.

For more than a century the commercial world has looked first to Great Britain for everything connected with iron. With her lower cost and large reserve stock she has been able to maintain a stability in prices and supply which has enabled her to control the markets of the world. The United States has for several years been the cheapest iron-producing country in the world, and should have begun making large exports of iron long before she did, but for ten years her reserve stock has been less than twenty-three days' consumption. If she is in the future to have uninterrupted control of the iron markets of the world, she must carry enough stock to give stability to prices. The higher cost and reduced product of Great Britain has prevented her accumulating her usual reserve during the last few years and will prevent this in future. The world's reserve supply in the future must be accumulated in the United States, and the introduction of the warrant system in this country has, therefore, been most timely.

British dealers have for eight years been among the largest holders of American warrants, and the introduction of them to exchanges in Great Britain is already under discussion. If dealings in American warrants become centered in London or Glasgow instead of New York, British dealers will still control the iron markets of the world, even after the principal supply comes from the United States.

Since the dawn of civilisation the importance of storing up stocks of such things as were necessary to the life, defence, and well-being of man has been recognised by all nations and people. The Scriptures, from Genesis to Revelation, abound in accounts of the immense store-houses and store cities builded and maintained by the great nations of ancient times. They not only gathered in the months of harvest sufficient to supply the people until the next harvest, but they stored up in years of plenty sufficient to provide for the years of famine. This wise provision ranked first in importance in all temporal affairs.

SIXTY YEARS IN BRITISH IRON WORKS

By George Beard

IN view of Mr. Beard's long term of experience in the iron industry of Great Britain, special interest is attached to the brief survey which he took of the subject in his recent presidential address to the West of Scotland Iron and Steel Institute, and, with slight modifications, this has, therefore, been reproduced in the following pages. Mr. Beard's remarks naturally were, to a great extent, reminiscent in character, and ought to readily conjure up a host of interesting comparisons.—THE EDITOR.

Early in the present century Great Britain imported more iron than was exported, and it will be interesting to note the production of pig iron and approximate prices of bar iron at Liverpool, so far as statistics are available, for the years referred to:—

Pig Iron Production, Great Britain.		Prices of Bar Iron, Per Ton.	
Years 1800	180,000 tons.		
" 1806	250,000 "	£16 0 0 to £17 10 0	
" 1827	690,000 "	8 15 0 " 10 0 0	
" 1840	1,400,000 "	9 10 0 " 10 0 0	
" 1851	2,750,000 "	4 10 0 " 5 0 0	
" 1854	3,000,000 "	9 0 0 " 9 15 0	
" 1865	5,000,000 "	7 0 0 " 7 15 0	
" 1872	7,250,000 "	11 0 0 " 16 0 0	
" 1898	8,817,109 "	6 0 0 " 8 15 0	

In 1827, of the 690,000 tons pig iron turned out in Great Britain, Scotland produced 36,000 tons, or about 5 per cent.; in 1854, of the 3,000,000 tons, Scotland produced 796,000 tons, or about 26 per cent.; and in 1898, of the 8,817,109 tons, Scotland produced 1,190,264 tons, or about 13½ per cent. In 1854 Mr. Kenyan Blackwell, a well-known authority on the manufacture of crude iron, in a paper read before the Society of Arts on the iron industries of Great Britain, gave the following figures to illustrate the production of iron in the various manufacturing countries of the world:—

Great Britain	3,000,000 tons.
France	750,000 "
United States	750,000 "
Germany	400,000 "
Austria	250,000 "
Belgium	200,000 "
Russia	200,000 "
Sweden	150,000 "
Other countries	300,000 "
Total	6,000,000 "

Looking at these figures it will be seen that in 1854, after the first great Exhibition of 1851, Great Britain produced as much crude iron as all the other countries of the world. Between 1854 and 1865 the pig iron increased in Great Britain to 5,000,000 tons. At this period Great Britain practically controlled and held the export trade of the world in iron and steel. It was the only country sufficiently advanced in the manufacture of iron in a position to supply the surplus requirements of civilised countries.

What is the state of things to-day? Great Britain, for the current year, is estimated to produce 9,000,000 tons, Germany 8,500,000 tons, and the United States 13,500,000 tons. From figures obtained from official sources, the world's production in 1898 was about 36,507,487 metric tons, an increase over a period of forty-five years amounting to about 30,000,000 tons.

Periods included in the figures I have quoted showing a special interest may be referred to. In 1872 the total production of pig iron in Great Britain was estimated at 7,250,000 tons. At the opening of the year Staffordshire bar

THE BLAST FURNACES OF THE ELSWICK WORKS OF SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE-ON-TYNE

iron was quoted £11 per ton at the January quarterly meeting at Birmingham. This was followed by successive advances until, in the month of June of the same year, it reached £16 per ton, the highest price recorded since 1806-7, when the production of pig iron in Great Britain reached the total of only 250,000 tons. In the same year, 1872, sheet iron of ordinary quality, 20-gauge, was sold at £21 per ton, and 24-gauge at £23 per ton.

The high prices of 1872 followed the conclusion of the Franco-German War and the collapse of the various industries on the Continent. They are the more remarkable when it is considered that two years previously, in 1870, bar iron was selling at £8 per ton. With the exception of the years 1806-7, a period when Great Britain had practically no export trade in iron, the high prices of 1872 were the highest recorded. The good trade in 1872 called forth the remarkable statement that "never in this country have prices been so high, the exportation and consumption so large, or the general diminution of stocks so marvellously rapid." Following these high prices came the inevitable reaction. Those of us who have been long in the trade have learned by experience the necessary consequences which follow an abnormal inflation of values. We may, or we may not, have made hay while the sun shone, but we have, at any rate, found time to reflect that those periods of trade are most satisfactory to employers and employed when prices are stable, and not forced unduly high or excessively low. In four months, between July and November, 1872, the price of bar iron was reduced £4 per ton. This reduction, without a corresponding reduction in the prices of raw material, disorganised the whole trade. The growth of the iron and steel industries of the Continent of Europe received their direct encouragement from the high prices ruling in Great Britain from 1872 to 1875.

Reviewing the periods of contraction immediately following expansions of trade and high prices, the difficulty experienced is to adjust prices in proportion to the relative cost of material and wages. To prevent positive loss, prices are frequently maintained longer than

changing circumstances justify. These circumstances give direct encouragement to foreign powers to erect works in all suitable localities, and we are today threatened with a considerable diminution of our export trade by the rapid increase in manufacture of iron and steel abroad. In the United States, Germany, Belgium, France, and lately Russia, competition was never so formidable as now.

According to carefully prepared estimates, the production of pig iron for the world in 1898 was about 36,507,487 metric tons, and the production during 1899 was approximately 40,000,000 tons.

We are all more or less aware of the present phenomenal demand for iron and steel of all manufactured descriptions, and with the output of pig iron in 1899 approximating 40,000,000 tons, and that of steel 28,000,000 tons, we have an increase of about 40 per cent. in the production of pig iron, and of about 88 per cent. in the production of steel, representing about five years' progress. This increase is truly marvellous, especially when we consider that it has taken Great Britain thirty-five years, from 1865 to 1899, to increase the production of pig iron four million tons, an average of about 110,000 tons per annum. Germany has equalled this in ten years, at the rate of 400,000 tons per annum, while the United States records an increase in four years of five million tons, an average of 1,250,000 per annum. The importance of the very large increase in the United States is more visible when comparing the remarkable year of 1872 with 1898. Great Britain during twenty-six years has increased the production of pig iron only about 1,500,000 tons. The United States exceeded this during 1898.

To the pioneers of the iron trade of the world this is, in some respects, humiliating. We have been, and are, in possession of the best developed coal fields in the world, and up to the year

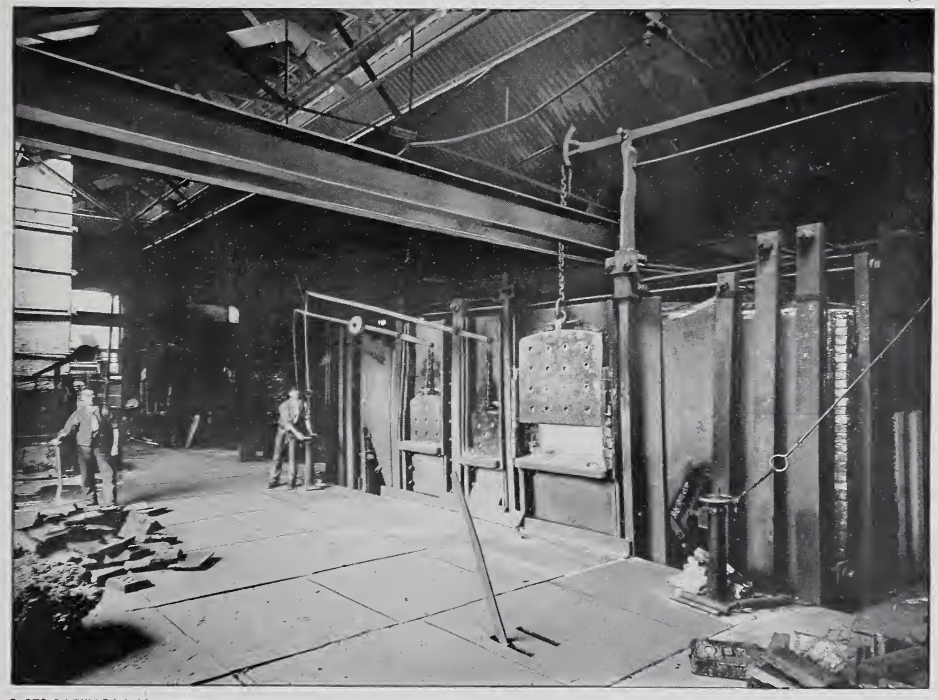
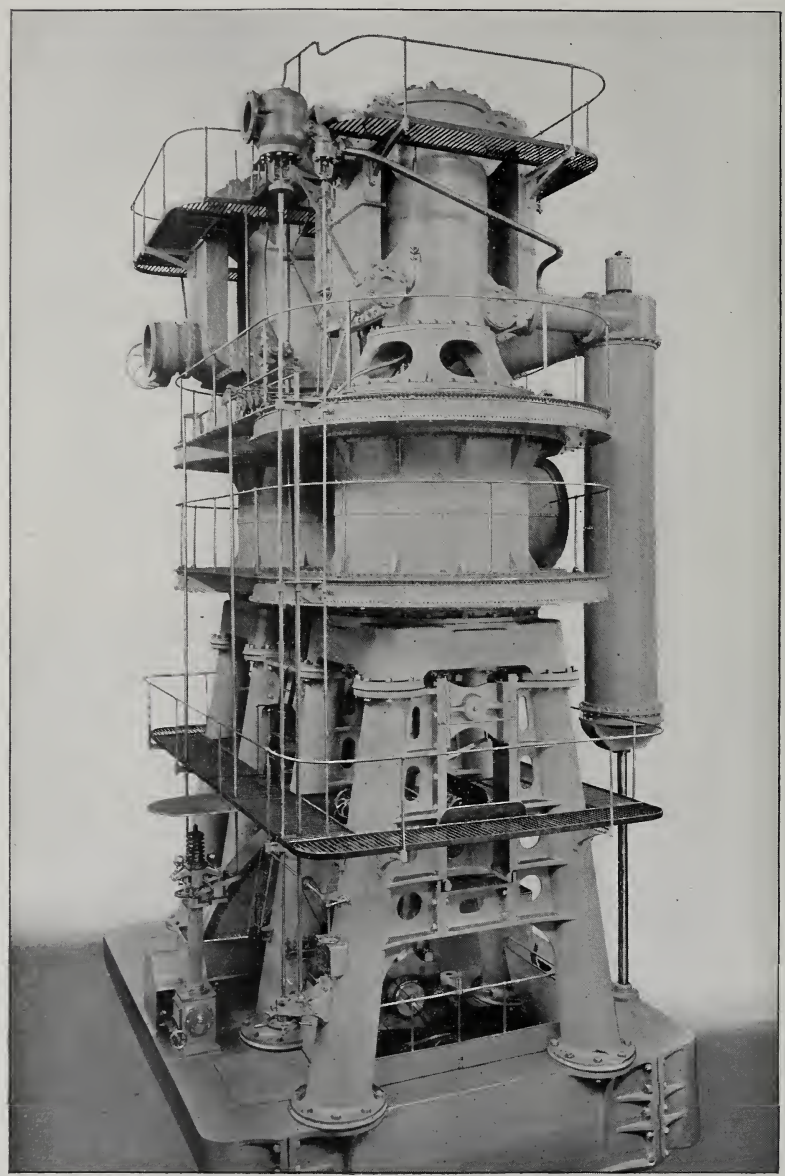


PHOTO BY TULLEY & CO , SHEFFIELD

SIEMENS-MARTIN FURNACES AT THE NORFOLK WORKS OF MESSRS. THOS. FIRTH & SONS, LTD., SHEFFIELD



A BRITISH COMPOUND BLOWING ENGINE, BUILT BY SIR CHRISTOPHER FURNESS, WESTGARTH & CO., LTD., MIDDLESBORO

1875, and perhaps later, we controlled the export trade of the world in iron and steel. Now we must take a secondary position, and, at the present rate of development, very soon a third.

But we have at least the satisfaction of knowing that Great Britain has produced the fathers of this mighty industry. I well remember Mr. Andrew Carnegie, as chairman of the reception committee, welcoming the members of the British Iron and Steel Institute to the meetings held in New York in 1890, acknowledging that "the debt which the new land owed to the old land baffled description. In the domain of iron and steel they had nothing whatever to show their visitors but the development of ideas from the old country. Cort, Neilson, Nasmyth, Bessemer, Siemens, Thomas, Gilchrist, and others were the inventors of the processes which they were now to see in force in the United States, and it had only been by these inventions that the amazing development of the country had been rendered possible."

We may well be proud that our country has possessed such a wonderful influence in developing the resources of the world, with its accompanying benefits to all mankind. The puddling-furnace, the hot blast, the steam hammer, the Bessemer, Siemens, and basic processes have been the chief factors in the development of the iron and steel industries, both here and abroad. These important processes have enabled Germany to take the fullest advantage of its mineral resources, and have placed the United States in the premier position as manufacturers of iron and steel. There are, however, other advantages which the United States manufacturers in particular possess which may be referred to briefly, the advantage most strongly impressed upon my notice, being thirty-five years of government protection. The protection obtained after the conclusion of the Civil War in the States gave a tremendous impetus to the development of the iron and steel industries there, and subsequent legislation has enabled them to control their own markets, and still further assist development. The nations of Europe, to

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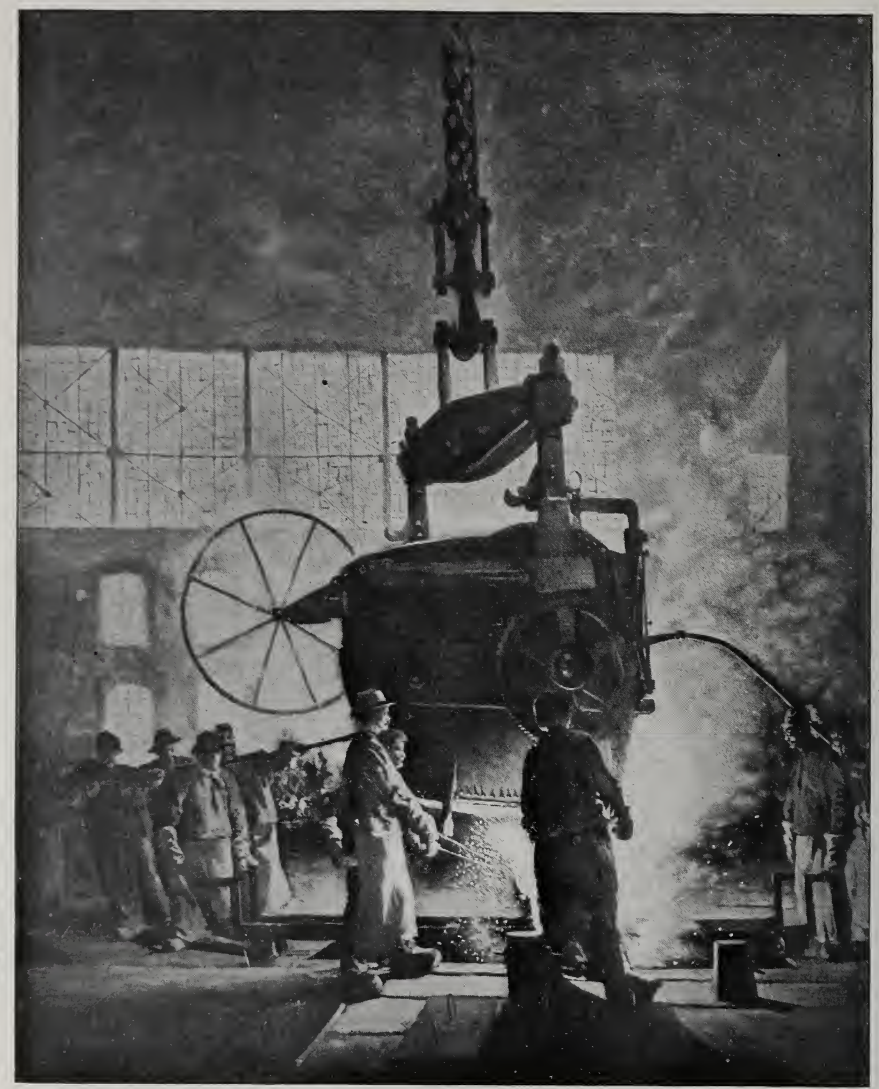
FINISHING ARMOUR PLATES AT THE WORKS OF MESSRS. THOS. FIRTH & SONS, LTD.



MAKING A CAST

a greater or lesser degree, have followed America's example.

In the sixties and seventies we commanded the iron trade of the Continent. These were times when France, Germany, and the whole Continent were excellent customers. Now they import mostly what we have little to spare of (to our great disadvantage), namely, pig iron. On the pig iron thus imported,—duty paid,—a rebate is made when re-exported in the manufactured form, and it is alleged that the rebate is calculated upon percentages of waste in the processes of manufacture greater than the actual. This means, of course, a system of indirect bounties. We open our ports free, irrespective of the means employed to intercept our trade. In return, we are practically excluded by unreasonable tariff and other conditions.

The policy of protection, with indirect bounties and government assistance in transport, has enabled Belgium,

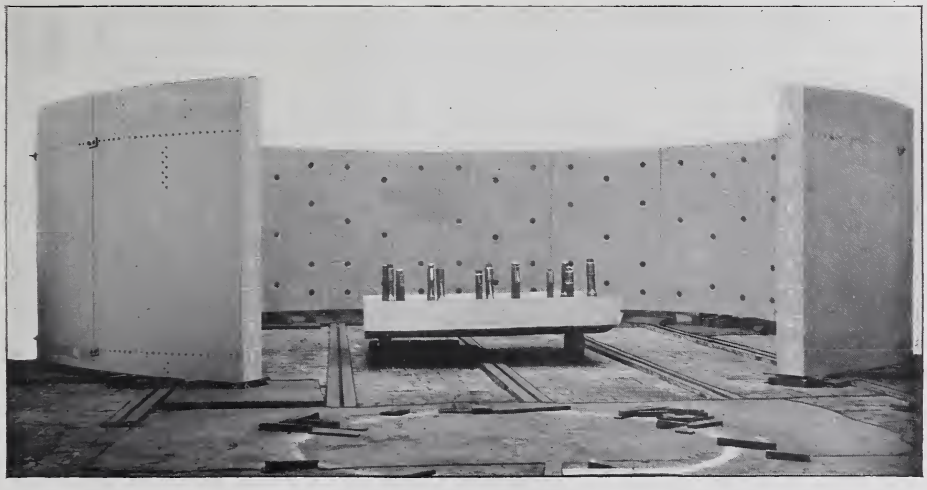
France, and Germany to obtain a substantial increase in their export trade, and to enter into successful competition with the manufacturers of Great Britain. This undoubtedly accounts for the comparatively slow increase in the production of iron and steel in Great Britain.

Amongst the features of interest connected with the wrought iron trades are the lowest prices recorded in 1854, £4, 10s. to £5 per ton, and the highest, in 1872, £11 to £16 per ton. The production in Great Britain for the year 1898 is returned at 600,566 tons; of this only about one-fourth, 150,503 tons, was exported, and amounts to only about one-half of the quantity exported in 1864. Bar iron being one of the staples of the iron trade of Scotland, it is unpleasant to know that the export trade of a production in universal demand is yearly decreasing, especially with the knowledge that for some years prices have been generally low and only reasonably profitable.

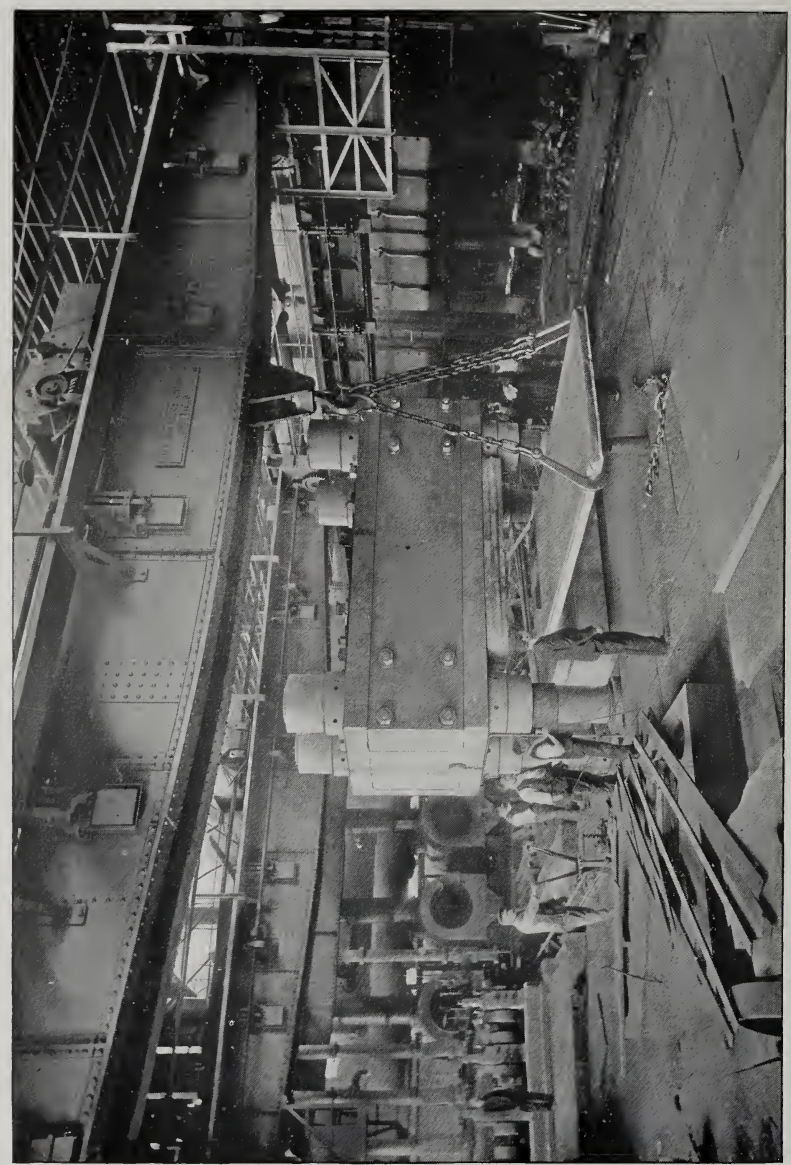
With regard to the increase in the consumption of bar iron for manufacturing purposes, it must be admitted that in Lanarkshire it is particularly noticeable in the additions to the list of firms engaged in the manufacture of rivets, tubes, and fencing. And, with respect to foreign competition, it must be granted that markets have been captured by others which were formerly our own. If there is any satisfaction to be derived from this, it is to learn that, in many instances, it is due to the cheapening of prices with a corresponding reduction of quality. We have been unable to produce a sufficiently cheap quality in bulk for certain markets, particularly India and China; and, I think, it will be found that British manufacturers are preferred at equal rates.

Speakers have not infrequently appeared to derive some pleasure, when referring to the comparative merits of Siemens-Martin acid with basic steel, to extol the acid open hearth to the disparagement of basic. In the early basic productions the absence of uniformity of quality doubtless enabled the acid manufacturers to obtain a decided preference to the serious disadvantage of the basic. For certain purposes all practical men know the one is to be preferred to the other.

Now that the basic and Bessemer basic processes have been improved, and a fairly uniform quality has been obtained, confidence has been established in the fact that Germany alone finds a ready increasing yearly sale of over 4,000,000 tons of pig iron made specially for the Thomas Gilchrist basic processes. The



HARVEYISED BARBETTE ARMOUR FOR H. M. S. "ILLUSTRIOUS" FROM THE WORKS OF MESSRS. CHAS. CAMMELL & CO., LTD., SHEFFIELD



A 6000-TON HYDRAULIC PRESS FOR BENDING ARMOUR PLATES AT THE WORKS OF MESSRS. CHARLES CAMMELL & CO., LTD., SHEFFIELD

United States are also large producers. In Great Britain the works established cannot overtake the demands for basic steel ingots, slabs, and billets. Basic and Bessemer steel has greatly superseded iron in the manufacture of beams, girders, and joists, also the use of coke iron (that is, iron produced in the old charcoal fire, coke being used in place of charcoal), and also best puddled iron for coke tin plates. Open-hearth steel, too, has displaced charcoal iron in the manufacture of charcoal tin plates. When Sir Henry Bessemer made his first experiments in converting Cleveland pig iron, made from the native iron ores, into steel he was astonished and disappointed to see, after the blast was turned on the converter, the molten metal blown away in sparks of fire, granular forms, and cinder. The old practical representatives of the iron trade, who were accustomed to the use of pig iron in the puddling-furnace made from the rich carboniferous argillaceous iron ores of the Midlands, exclaimed, on referring to the quality of the metal operated upon, "If nothing is put in, verily nothing is produced." This was the turning point. Mr. Bessemer, with his indomitable perseverance, fled from the use of low-grade pig iron to the richest quality made from hematite iron ores. It was only by ignoring all other descriptions that he succeeded in utilising his splendid inventions.

Dr. Siemens also could perfect the open-hearth process only by excluding all pig iron made from iron ores inferior to best hematite.

The facts are established that while open-hearth acid steel holds its own position, and finds a ready sale, its uniform quality depends upon the continuous supply of best hematite iron ores. Upon this also depends the successful production of Bessemer steel for rails and other purposes. It is estimated that the Bessemer, acid, basic, puddling, and iron founding processes or trades required from eighty to one hundred million tons of iron ores of various qualities smelted into pig iron during 1899. The enormous yearly increasing demand is sufficient to impress upon the minds of all interested that we cannot afford to depreciate any one of the processes that can be satisfactorily and

PHOTO BY TULLEY & CO., SHEFFIELD

FORGING SHOP OF MESSRS. THOS. FIRTH & SONS, LTD.

CASTING TIME IN A CRUCIBLE DEPARTMENT

profitably used to supply the world's requirements of iron and steel.

While the production of basic steel and its resultant manufactures has not prejudiced the production of open-hearth steel, it has, to a considerable extent, supplanted the use of wrought iron, and will, in the near future, challenge the existence of the malleable iron trade, not because in all cases it is to be preferred, but chiefly because of its possibilities of increased production and reduced cost of manufacture.

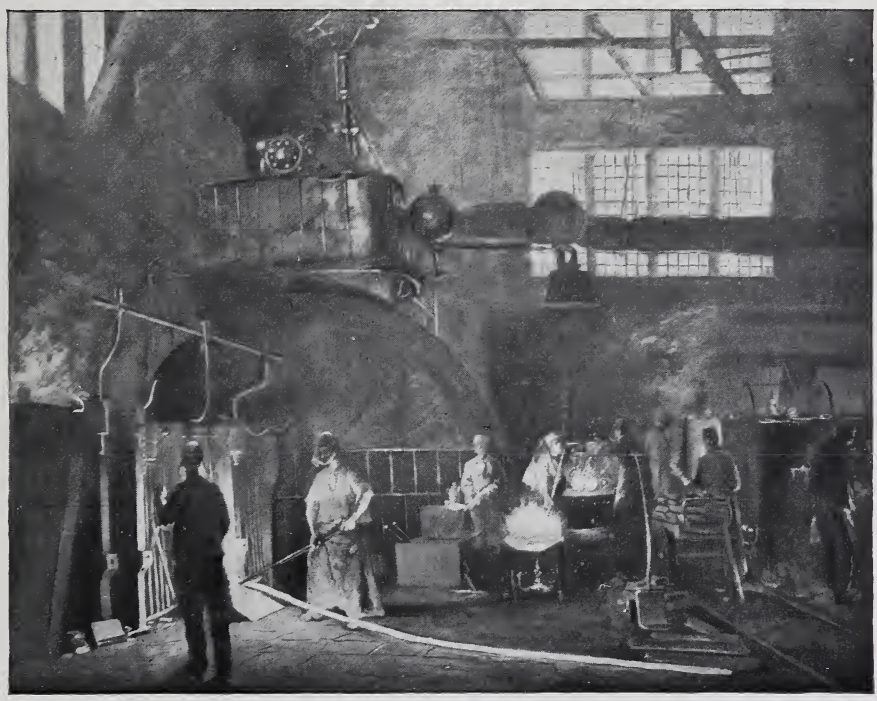
The existence of the puddling-furnace depends upon the character, habits, and reasonable intelligent interest that the puddler takes in his work. While puddling is possibly the most monotonous, it is also the most scientific operation to the diligent worker in the wrought iron trade.

In the three important processes which have contributed most to the expansion of the iron and steel trades, we have great improvements, but nothing new. The wrought iron rails manufactured for the first passenger railways were produced from pig iron obtained by smelting the carboniferous argillaceous native iron ores previously referred to. The pig iron was refined in the open refinery under a pressure of blast, and coke was the fuel used. The refined metal obtained was afterwards puddled on the open-hearth sand bottom. The balls from the puddling-furnace, after they were hammered into flat slabs, were piled in sufficient number to make the weight and length of rail required. They were then heated and again hammered into ingot shape, and either reheated or rolled direct from the hammer into the section of rail required. By these processes a splendid quality of rail was obtained. When it was found that the cost of production could be reduced by using common qualities of pig iron, the refinery was abandoned, and, in the

interest of pig boiling, it became a common practice to fettle or line the sides of the puddling-furnace with limestone.

The great difference between the processes so largely employed in the manufacture of steel and puddling is that these processes are one continuous operation of refining under intense heat in order to eliminate the chemical and earthy impurities,—the character of the metal depending upon the duration of the refining and the carbonising influence adopted, while, in puddling, the operation is conducted under a lower temperature to facilitate "boiling"; the moment the boiling is complete an absolute conversion takes place, the pig iron, or cast metal, being changed into wrought iron. During the process, after the pig iron is melted, the melted fettling or lining and cinder, used to protect the furnace and assist the process, floats on the fluid metal. When the pig iron and cinders are all melted, puddling proceeds until the boiling is complete. At this stage the fluid cinder, with the impurities, sinks to the bottom. The puddler then proceeds to divide the iron into balls for the hammer. The quality of the product depends upon the skill of the puddler in dividing and balling the iron in a manner to permit free precipitation of impurities so as not to be wrapped up with the iron in balling. After the balls are hammered and rolled, if the best qualities of pig iron are used, the bars produced will, on testing, exhibit good, fibrous, tough, homogeneous quality, and, if the common qualities of pig iron are used, an open crystalline fracture.

After the introduction of puddlers' tap cinder into the process of smelting and the free use of the more plentiful and cheaper ores of the "oolite" formations in the production of pig iron, it was found advisable to use one of the following three forms of squeezers:—The "Jerry Brown" consisting of horizontal rollers, the "Coffee Mill" of one large vertical roller, or the "Crocodile" shape (see pages 113 and 115), to com-

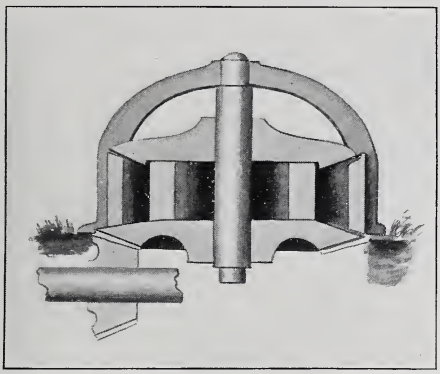


A ROLLING MILL VIEW

PHOTO BY TULLEY & CO., SHEFFIELD

CRUCIBLE FURNACE DEPARTMENT AT THE WORKS OF MESSRS. THOS. FIRTH & SONS, LTD., SHEFFIELD

press the puddled balls into bloom shape for rolling into bars in place of the old metal helve hammer. The object was to retain the cinder under compression to assist the welding throughout the process



A "COFFEE MILL" SQUEEZER

of rolling, and when finished into a rail, angle or other section, to obtain the comparative softness necessary to allow of cold straightening and punching. The same material subjected to treatment under the continuous blows of the metal helve hammer was found practically valueless on account of extreme brittleness.

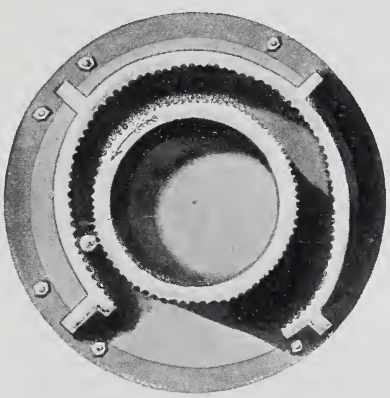
In 1842-4 the writer was employed to assist the plate-roller in a plate-rolling mill. The pig iron from which the plates were rolled was first refined in the open-hearth refinery, and afterwards puddled, the puddled balls being hammered into slabs in sufficient number to produce the weights and size of plate required. The pile of slabs was then heated to a welding heat and hammered into slab shape, large quantities without reheating being rolled direct from the hammer into plates. For some purposes the slabs were reheated before rolled.

Several years after this early experience the writer witnessed the rolling in South Staffordshire of the plates for the first iron ship of special note, *The Great Britain*, by a similar process to that described, except that at the time this ship was being built it was the practice to puddle a mixture of refined metal and best pig iron. This was before the manufacture of pig iron from the oolite iron stone and limestone formations.

The plates were of the highest quality of iron obtainable at the period named, and, if the quality of iron then produced had been maintained, we should have heard less about steel ships and Lloyd's survey, and I venture to think that shipowners would have obtained a longer life of service from their vessels if they had been built of iron of the quality used for *The Great Britain*.

The sizes of plate used in the building of this ship were 7 to 8 feet in length by about 2 feet in width, and it is interesting to compare these dimensions with the large area of steel plates now employed in shipbuilding. This small size of plate was made to suit the convenience of hammering the slabs under the metal helve, the action of which is somewhat similar to the tilt hammer.

Antiquated as the metal helve now is after the general use of the steam hammer, it is still preferred at some works producing the best iron on account of every puddled ball receiving the same weight of blow and uniform treatment, whilst under the steam hammer the



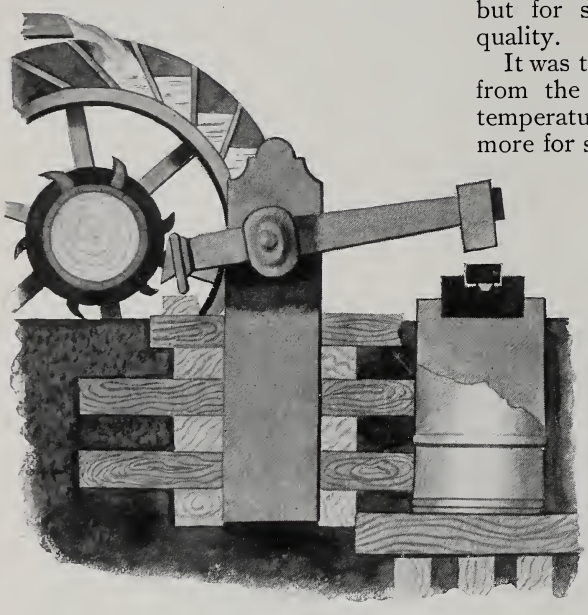
A TOP VIEW

weight of blow is regulated, light or heavy, by the steam hammer driver to suit the condition in which the balls are brought under the hammer.

The steam hammer may be used merely for the process of squeezing, as in the older forms of squeezers, but

here, too, the same uniformity of quality is not obtained as compared with iron hammered by the metal helve. This uniformity is at all times very desirable, and for certain manufactures, such, for instance, as chain making, it is an absolute necessity.

Before leaving the process of hammering the writer would mention that during the years 1855-7 he rolled plates for flanging into full-sized smoke-box ends of locomotive boilers from slabs hammered under the metal helve into rectangular shape about 18 inches wide,



A TILT HAMMER

5 inches to 6 inches thick, weighing from 12 to 18 cwt. each.

Previous to the writer's employment as a plate-roller in 1854, he was employed as a sheet-roller. At that period crown quality of sheet iron was produced direct from a first-class quality of puddled bar. Thousands of bundles of 24-gauge sheets were rolled for the United States direct from the puddle bar without any further preparation, the sheets being used for ordinary working-up purposes and roofing. For best quality, the same puddle iron was used, cut into lengths, piled and heated in the ball or mill furnace, sometimes hammered, and at other times rolled, without hammering, into bars. These bars were cut into lengths and rolled at about a red heat into sheets. The sheets were branded "Best," or, if refined metal had been used in the puddling furnace, they were branded "Best Refined."

It was from the process just referred to that the phrase "Best Refined" originated, and although the process has practically disappeared, the phrase "Best Refined" is still largely employed as a brand, not as a brand for sheets and bars of the highest quality, but for sheets and bars of common quality.

It was the custom when rolling sheets from the puddle bar direct at a low temperature to charge 30s. per ton more for sheets (to 20-gauge) than for crown quality of bar iron. For 21-24-gauge the extra was 30s. per ton over the price of 20-gauge, and for 25-27-gauge 30s. per ton over the price of 21-24-gauge. If the sheets were rolled from the same quality of puddled bar, ball-furnaced, hammered, and re-rolled into a bar, or, if rolled from merchant bars, it was customary to charge an additional 20s. or 30s. per ton on all gauges.

With a view to produce a more uniform quality of sheets than was obtained from rolling direct from the puddled bar, and to obtain a best sheet at a less cost than from a specially prepared ball-furnace or merchant bar, Messrs. George & Edward Thornycroft introduced groove rolls into their sheet rolling mills at Bradley, near Bilston, for the purpose of rolling sheets from piles. This method of rolling enabled them to produce a tough and fibrous sheet free from forge or mill scale, which was preferred to the sheet produced from the very often carelessly rolled shingled puddled bar. Being softer and more homogeneous for seaming and folding, it was extensively used in the manufacture of domestic utensils and other gen-

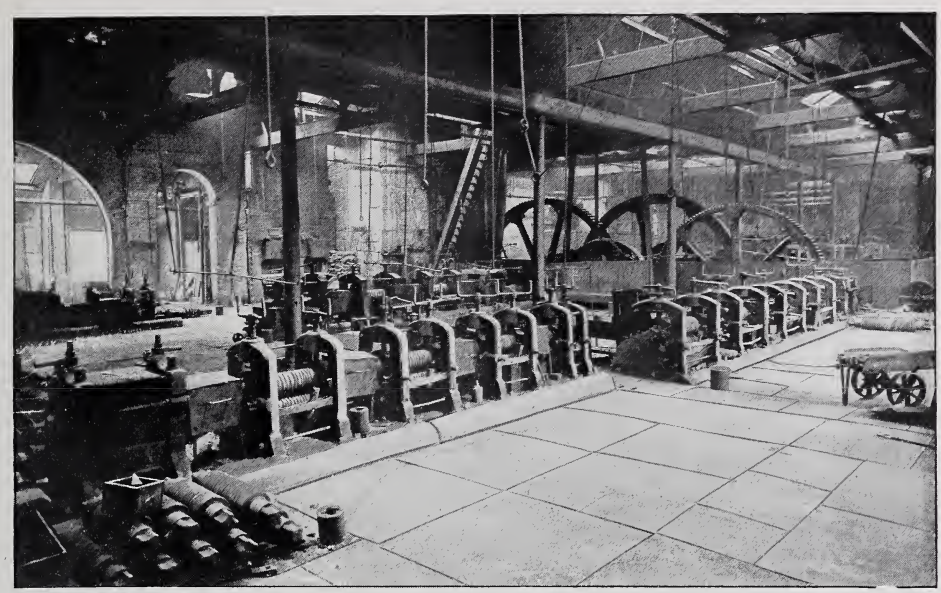


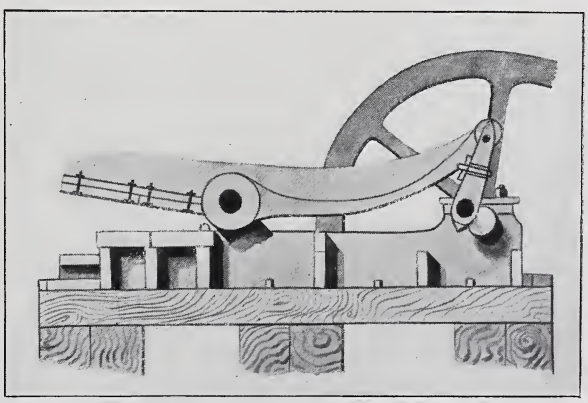
PHOTO BY TULLEY & CO., SHEFFIELD

ROLLING MILLS AT THE WORKS OF MESSRS. THOS. FIRTH & SONS, LTD.

eral work which commanded, on its first introduction, an extra 10s. to 20s. per ton more than "Best" sheets rolled from ball-furnace bars.

The process opened the door for the use of commoner qualities of puddled iron and for the development of the sheet iron trade, a trade in which the competition increases daily. The increase of rolling mills in Belgium and Germany competing for our Eastern trade, the loss of the American market, on account of prohibitive tariffs, the conversion of tin plate mills in South Wales into sheet mills, consequent upon the said tariffs also affecting the tin plate industry, all these factors have resulted in a remarkable change in the relative values of sheet and bar iron. And this fact could not be more strongly emphasised than when it is stated that in 1898 27-gauge sheets for galvanising and corrugating were sold in South Staffordshire at a lower price than was paid for marked bars. The loss of the extras on piled rolled sheets, together with the extraordinary waste in the process as compared with the rolling direct from a well-made bar, has resulted in the return to direct rolling, now that the introduction of basic and Bessemer steel bars has made it possible. Pile rolling has, to a great extent, been abandoned, and is likely to disappear altogether unless the present high prices of steel bars induce a return to it.

With the exception of what I have referred to, there is nothing new to re-



A CROCODILE SQUEEZER

port in the processes employed in the rolling of sheets in this country. At the beginning of the present century the writer's grandfather rolled sheets for tin plates at Framilode, in Gloucestershire, and, except that the design of the rolling mills was more primitive, the process of rolling was just the same as that employed to-day.

One more reference! Sheet-rollers nowadays consider themselves clever workmen when they are required to roll a 20-gauge sheet four feet wide. Between 1845 and 1857, and before papier maché came into extensive use, large quantities of iron sheets were made for stamping into trays which were japanned and beautifully decorated,—no housewife's equipment was complete without a large-sized tray. The writer's first experience as a sheet-roller was in rolling sheets for stamping into trays. An Egyptian Pasha, after a visit to England, sent an order for a number of large-sized trays for use in his harem. To produce these trays, sheets were required five feet wide in 20-gauge, weighing 1½ pounds per square foot. Not a single manufacturer would undertake the rolling without an agreement from the buyer to make good any damage to the machinery that might occur in the process of rolling. The guarantee was given on the writer's father consenting to roll the sheets. These were produced without accident. At the time it was considered an extraordinary feat in sheet rolling, and cannot, so far as the writer knows, be beaten to-day.

Reviewing generally the various periods of high prices since 1840, it will be found that temporary advantages have encouraged manufacture and competition in and out of Great Britain to formidable dimensions. What the effect of this will be in the twentieth century remains to be seen. It points, however, to the survival of the fittest. All our ingenuity, all our perseverance, all our tact and devotion, will be required to enable Great Britain to hold its own. The existence of private firms which represent individuality will greatly depend on the tolerance of the trusts and syndicates which are so rapidly absorbing small interests, and which, in times of depression, will be anxious to obtain orders to pay on cost, fixed charges, salaries, and commissions, not to speak of profit to shareholders.

PRACTICAL INVENTING

SUGGESTIONS IN SYSTEMATISING INVENTIVE EFFORT

By W. H. Smyth

THE inventive faculty is recognisable solely by its product. The courts and patent office say that an invention is recognised solely by being the product of the inventive faculty. Assuming these propositions to be true, which is to be the criterion, the faculty of the product, or the product of the faculty? Then, what shall constitute a test of the criterion itself,—a test by which to settle that ever-recurring question of the presence or absence of invention in the production of patented devices and those on which patents are refused by the patent office?

Incidentally it may be noted that, gauged by these tests, the inventive faculty is a very old institution, indeed, far older than the human race. Patents have been granted on artificial honeycomb. Patent honey, too, has formed the subject-matter of long and costly litigation, in which, by the way, the rights of the bee as first inventor have been ignored, though it could have proved indisputable priority of invention with one exhibit,—a sample of fossil honey-comb.

Leaving, for the present, these misty and unsubstantial questions to the metaphysicians to whom they rightfully belong, let us, as common sense mechanics, address ourselves to the really important and practical issues connected with the production of new and original machines! In the production of mechanical inventions is it possible to discard rule-of-thumb, empiricism, and hap-hazard groping for inspiration, all of which are foreign and discordant to the normal mental attitude of the mechanician, and substitute therefor system, method, logical reasoning, and common sense? Is it possible by such means to produce inventions which, while accomplishing their mechanical intention, will be of such character that the patent office and courts will, without hesitation, stamp them with their approval and extend to them freely and fully the consideration and protection accorded to the products of the supposititious inventive faculty?

The writer's purpose is to show that these practical questions must be answered in the affirmative. It is, of course, obvious, even to the least observant, that every invention displays a logical relation to its purpose or to the need which it supplied. So obvious, indeed, is this that the expression, "Why was it not thought of long ago?" has become trite. Of itself this natural mental attitude assumes the very matter for which the writer would contend.

A want, if clearly appreciated and fully understood, will be satisfied by normal mental processes (logical reasoning), providing the appreciation and understanding are present in a mind furnished by experience with the material necessary to the accomplishment of the purpose. Such a satisfaction, when expressed in tangible form, is an invention. This sounds more formidable than it really is. It is merely stating in another way that "to know is to prophesy." It asks no greater assumption than that upon which all our everyday conclusions are based,—cause and effect. The other contention, on the contrary, asks of us to mentally harbour that bugbear of common-sense, the production of something from nothing,

effect without cause, — spontaneous creation.

In an investigation to determine how any other ordinary product of human endeavour had come about, with the object of becoming skillful in producing similar things, the natural course would be first to examine carefully and critically all the facts available relating to its origin. Having determined from many examples and matters analagous thereto that a principle was involved, the next step would be to formulate a common-sense theory and proceed on this in attempts to produce like results by the employment of means similar to those adopted in the production of the investigated product.

The difficulty of illustrating this line of thought, apart from that inherent in written description, is not in the dearth of illustrations, for they are seen on every hand; it is almost wholly involved in the problem of retracing inventive operations.

FIG. 1

An inventor seldom notes the road he is travelling; his attention is fixed on the goal for which he is striving. His path is seldom a direct one. The goal itself is not infrequently a different one from that to which he directed his course in starting. He may, it is true, remember some of the obstructions which impeded his progress and some of the difficulties encountered, when the rare necessity arises of determining the way taken in arriving at his objective point, but it is seldom that a complete record is available.

The goal of the inventor is always in new and unmapped regions, and when reached it serves simply as a starting-point for others. His foot-prints are at once obliterated by the multitude who press closely behind. His path then has become the beaten road of common knowledge, from whose well-defined course all obstructions have been removed, so that it is difficult to appreciate that they ever existed.

Court records of patent suits approach nearest to supplying the desired data, and they invariably show, step by step, growths or evolutionary processes in the genesis of inventions. In no instance within the experience of the writer has such an investigation failed to disclose almost indivisible steps, extending frequently over terms of years, by which improvements in an art progress. So invariably is this the case that the courts have been compelled to hold, as a settled rule of patent law, that it is "the last step" which counts. The "prior art" is always the bugbear of the patentee; it is equally the joy of the infringer.

To the investigator in this line of inquiry such records are both surprising and instructive. To an unprejudiced mind they appear conclusive that inventions are the result of experience, specialised skill, and clear-headed reasoning. They are invaluable, too, as showing not only how inventions have been made, but how they must be made.

As this is directly in the line of the present inquiry, it will prove interesting to note briefly the salient points in the growth of an invention which has passed through this ordeal. For this purpose one has been selected which appeared to lack every suggestion of evolution. One, which on account of its completeness, its radical departure from previous practice and entire lack of prior art, seemed a peculiarly apt demonstration of the "spontaneous creation" function of invention.

This invention appeared in the seventies and sprang at once into general use, filling completely an obvious need, and has since suffered no substantial or material change. From the maker it came complete "a pioneer invention," to all appearances a "spontaneous creation," a "flash of thought," "an inspiration." Listen now to the story told by the court records! The events they recall commenced not in the seventies, but nearly a quarter of a century earlier.

In 1853 experiments were undertaken

by the man who afterwards devised the hydraulic dredge, the invention referred to, for the purpose of determining the silt-carrying capacity of water in channels or open conduits (Figs. 1 and 2), to be employed as filling for mining dams in the mountainous gold fields of California. Several years later these experiments were extended in an endeavour to apply the same principle to building levees to restrain the streams and reclaim the marsh and overflow land of the Sacramento valley.

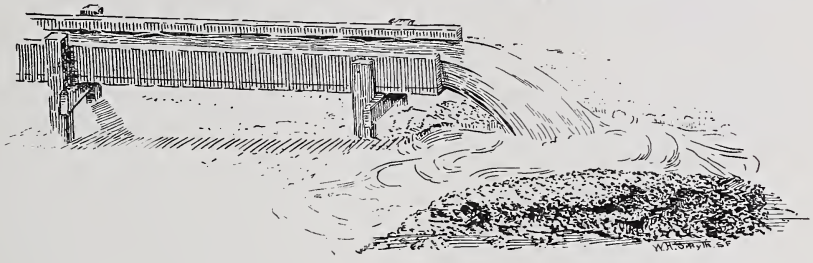


FIG. 2

Here it is observed that the conditions radically changed, unlimited inclines of the mountains for the levels of the marsh necessitating change from an open channel to a closed one. Artificial currents consequently had to be substituted for those due to gravity. But here the first difficulty was experienced. To get material into a rushing stream flowing in an open trough is one thing, and into one in a closed pipe quite another.

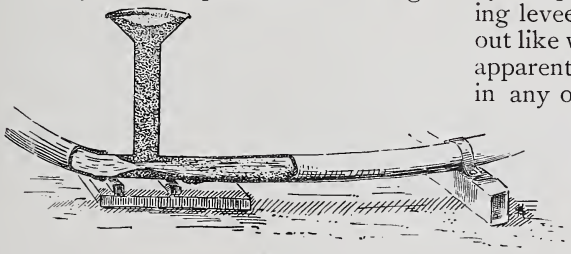


FIG. 3

However, after numerous experiments this was accomplished by the employment of a "pressure column," that is, a deep, long-necked hopper, fixed vertically on the pipe near a sort of injector nozzle throwing a powerful stream of water. This device (Fig. 3) proved satisfactory, and the capacity of the closed conduit as a spoil transporter exceeded in astonishing measure the most sanguine anticipation. It was found that by this method spoil could be carried long distances even up slight inclines.

Here, then, was a simple means (Fig. 4) adapted to transport continuously immense volumes of spoil to practically any desired place, and, by supporting portions of such a carrying pipe upon floats (Fig. 5), to carry it over water. At this point difficulties crowded thick and fast. So grave, indeed, were some that, for a time, they threatened the entire utility of the results and more than suggested the utter futility of all the past efforts.

The fluidity of the material carried by the pipe rendered it useless in making levees or embankments. It spread out like water. It became depressingly apparent also that the bucket dredge in any ordinary form (Figs. 6 and 7) was ill adapted to handle river silt in the practically fluid condition necessary for pipe transportation. Pipes naturally suggested pumps, and it was well known that muddy water could be pumped. It was known also that centrifugal pumps had been successfully employed (Fig. 8) in emptying tanning vats, readily carrying up the tan bark. The availability of the centrifugal pump for handling spoil suspended in water was thus readily inferred.

This step, though a long one, served but to bring the obstacles still to be surmounted nearer and into greater promi-

nence. A spoil-transporting device of great capacity and adaptability had been evolved, but a dredger or spoil excavator of equal efficiency, suitable to act with it, seemed beyond the power of ingenuity to contrive, and for a long time progress was blocked. The requirements of this needed device, roughly enumerated, were:—capability of severing and dislodging all kinds of

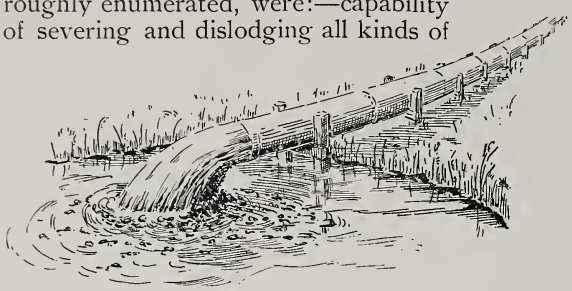


FIG. 4

material met in dredging; continuity of operation; the material to be delivered therefrom in condition for transportation through a long pipe; and, finally, the delivery of the prepared spoil into the interior of the transporting pipe.

It was not until 1864 that these conditions were fulfilled. A sentence in an old encyclopedia of mechanics made available the needed material, which, with that already acquired, gave the clue to a combination which satisfied the requirements:—

"Balme, in 1630, made a vertical wheel which worked between two boats, armed with six buckets, which lifted a vast deal of mud" (Fig. 9).

Such a wheel could feed a "pressure column" of the early experiments. The pressure-column-wheel (Fig. 10) was getting "very warm" on the hydraulic dredger, as children say in the game of hide-and-find. This combination evidenced a capacity of not only lifting a vast deal of mud, but also of transporting it to any desired place on land or water. But an excavator which can lift "a vast deal of mud," even when combined with a transporting device capable of taking care of it, does not constitute a dredger. The problem still remained of devising means to direct this excavator wheel so as to supply a continuous flow of spoil to the transporting pipes. Then there was that other constraining requirement,—the dredged bottom must be left smooth and free from hummocks or undredged portions.

This problem of control has been the stumbling-block of wheel-dredger inventions in the past, for attempts to apply wheels to dredging had been numerous. It was obviously impossible to feed continuously forward in shallow water unless the wheel were made as wide as the boat, an extremely undesirable construction. The only alternative was side feed. Chain bucket dredgers had employed this method (Fig. 11) of seeking fresh material, cutting a series of independent trenches, radiating from a pivotal anchor. But this involved intermittency, which, though of no particular moment in the loading of a barge or dumping directly on shore, was inherently at variance with the needs of the pipe method of transportation. The arc feed was adopted, and, by giving side-cutting edges to the excavator buckets, continuous side motion

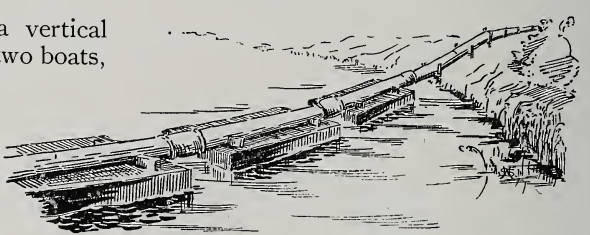


FIG. 5

was provided for, giving the added capability of varying at will the amount of material fed into the carrying stream by fast or slow side-way motion.

Thus was made available:—a transporting device adapted to carry material in fluid suspension to long distances over land or water; a device adapted to raise disintegrated material from its resting place at the bottom; a continu-

ously operating, severing and disintegrating device adapted to deliver its material to the raising and transporting device; and lastly, means for progressively advancing in determinable direction.

These separate, component wants being satisfied, bringing the necessary material within the consciousness of a logical mind, does not the logical satisfaction of the fully appreciated compound want follow and proceed as the necessary and inevitable result, the want itself forming the nexus to crystalise the parts into a complete unified whole, the physical expression of which is an invention,—the hydraulic dredge? This last step, this unification, would it not naturally have the appearance of suddenness? The records show this, in the present case, for the sketch (Fig. 12) was made as the immediate result of the Balme wheel suggestion.

The foregoing process of evolution, moving so easily and smoothly in the telling, is shown by the records of which it is the merest outline, to have been, in reality, a long, wearisome, and halting journey, extending over ten years, with ten still more trying ones to follow before the final demonstration (Fig. 13) in operative mechanical form. Many of the steps, digressions, twists, and turns have been omitted. Hundreds, if not thousands, of sketches and drawings were made. Models of paper, of cardboard, of wood, of brass, tin, and iron, in most surprising number, tell a tale of industry, persistency, courage and devotion.

Where, in this "Pilgrim's Progress"

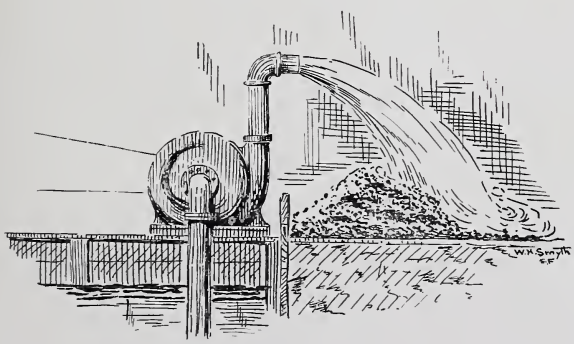


FIG. 8

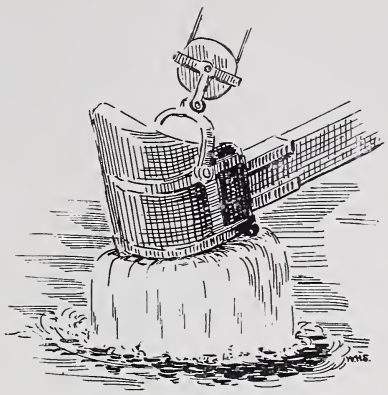


FIG. 6

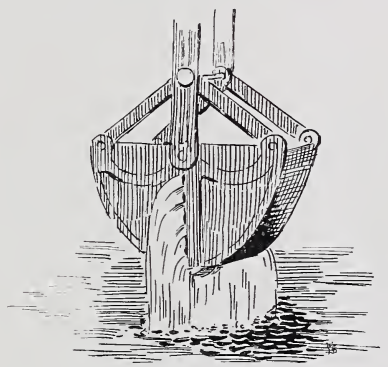


FIG. 7

of patient toil, is to be found "spontaneous creation?" Is there anything here which suggests "the opposite of reason or inference," as one of the leading authorities characterises the inventive act, or anything compatible with the dictum of another equally eminent authority that "when the mind invents, it starts with the conclusion: the conclusion flashes, so to speak, upon the mind?" Does it not, on the contrary, disclose steadfast, persistent effort of a logical mind, strong in the courageous conviction of its own conclusions? Does it not show the common-sense application of the material derived from careful observation of commonplace things to the satisfaction of definite ends? Is not this conclusion inevitable? Change but the detail

and the story will fit the production of every great invention.

Could I recount the stories of a dozen of the epoch-making inventions, simply as unadorned records of scientific data, my task would be effectually accom-

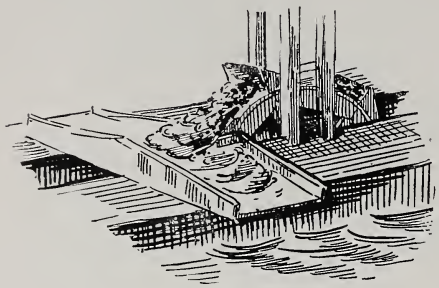


FIG. 9

plished. These records would make conviction irresistible and demonstration complete that inventive genius in final analysis comprises the same qualities which in all directions of human activity make for progress and betterment, courage, common sense, and industry,—mechanical invention,—these qualities applied to mechanical problems.

Common sense and industry make a good citizen. Courage, common sense and industry make a great man, whether he be scientist, statesman, mechanician or trader. They differ but in the material with which each deals. Imagination is but pictorial or visual memory, a necessary ingredient in mechanical comparison, inference and judgment, *i. e.*, common sense. One other matter these records show with equal clearness, namely, an amazing lack and need of system, order, and method in the direction of effort and a most prodigious waste of time and vital energy as a result of this unscientific, hap-hazard empiricism.

Returning to the dredger, assume the time element eliminated from the constructive process; consider all the steps to have been mental operations dealing with knowledge of facts previously acquired, instead of being the result of experiments labouriously and haltingly made to fill gaps and supply necessary knowledge. The operation becomes at once an analytical process pure and simple. These are not far-fetched or unwarranted assumptions, for some of the steps appear to have been entirely of this character, the tanbark inference, for example, also the Balme wheel and pressure column. Such an analysis, deliberately undertaken, might have pursued something like the following course:—

Problem:—To provide means adapted to excavate submerged land and transport the severed material to a desired position.

The problem is obviously divisible into 1st, means for severing the material; 2d, means for raising the material; 3d, means for transporting the material; 4th, means for progressive advance to obtain material.

Each of these divisions is sufficiently independent of the others to be dealt with separately. Excavating is a slicing or disintegrating process, involving knives or teeth moving in straight or circular paths, with a preference for the circular as being continuous. Such an excavator would leave the material in a condition analogous to the bark in the tan vats, suggesting similar means for raising. Rapidly flowing mountain streams erode alluvial banks and carry large percentages of such material in

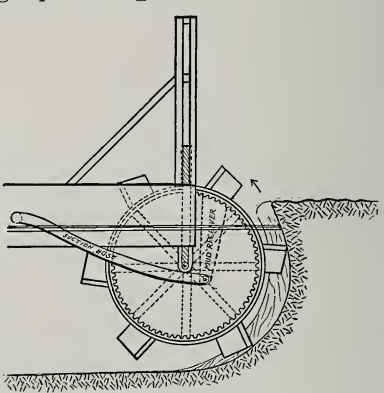


FIG. 10

suspension. And so on with the several components. It is hardly necessary to carry the illustration further; this sufficiently indicates the possibility. In effect, the real process which has been followed was essentially similar,

but pursued unconsciously and unmethodically, with consequent lack of economy.

It may be urged that the analysis of an invention is analogous to analysing prophecy after the event. No amount of proof that the facts prophesied must have transpired in the natural order of things would account for the Sybiline gift or enable one to acquire it. And by the same reasoning, inventions being in, and concerned with, a world governed by law and fixed conditions must accord with the natural order of things. Consequently, though they be the product of "spontaneous creation," they may be analysed, and the elements so separated would naturally, if arranged, produce the same invention as that brought about in the first place by a creative act.

This argument is obviously specious, though usually urged with the great appearance of candour. It assumes the very essence of the contention. The natural order of subsequent events is no proof against prophecy, but could it be shown that, at the time an oracle was uttered, all the conditions were present, the mere observation of which by a trained mind must, as cause and effect, have predicated the foretold event, then surely must the necessity of the miraculous give way to the more commonplace explanation of logical analysis and synthetical reasoning. The same is true when applied to the production of inventions.

Foretelling the weather for days, or astronomical epochs years, hence has now no savour of mysticism. Why the musty odour of occultism should linger around this other and wholly modern form of prophecy, mechanical invention, passes comprehension. It is an anachronism. Mechanics is an exact science; it deals with material things and measurable quantities; its problems should be, and are, as subject to law and reason as those of any other physical science. Our knowledge of the laws governing matter and motion is complete, at least so far as they concern machinery and the things with which machinery deals. Why then adhere to cut-and-try, rule-of-thumb, and childlike empirical methods which are obsolete in other departments of physical science?

The trouble appears to be due to the fact that inventors, as a class, have been almost invariably recruited from makers. They have been evolved with some degree of suddenness from actual hand-workers who, with merely their hands and a sharpened piece of metal, have fashioned things adapted to their simple needs by a laborious process of

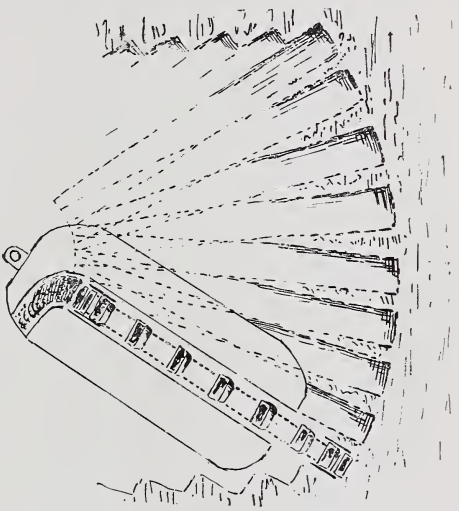


FIG. 11

whittling. They still depend on their hardly acquired manual skill, and have not yet learned to use the higher form of dexterity which employs the infinitely plastic images and concepts instead of refractory physical things themselves. The art is yet in embryo whose craftsmen consciously, skillfully, and intelligently employ that wonderful mental handicraft which has been unconsciously attained with, and by reason of, the acquirement of physical manual skill.

To attempt the accomplishment of a mechanical purpose without having first determined accurately the nature of the end sought is as illogical as it would be to start on a journey without first ascertaining the location of the desired destination. To carry the analogy a step further, the goal having been geographically established, the forces of nature

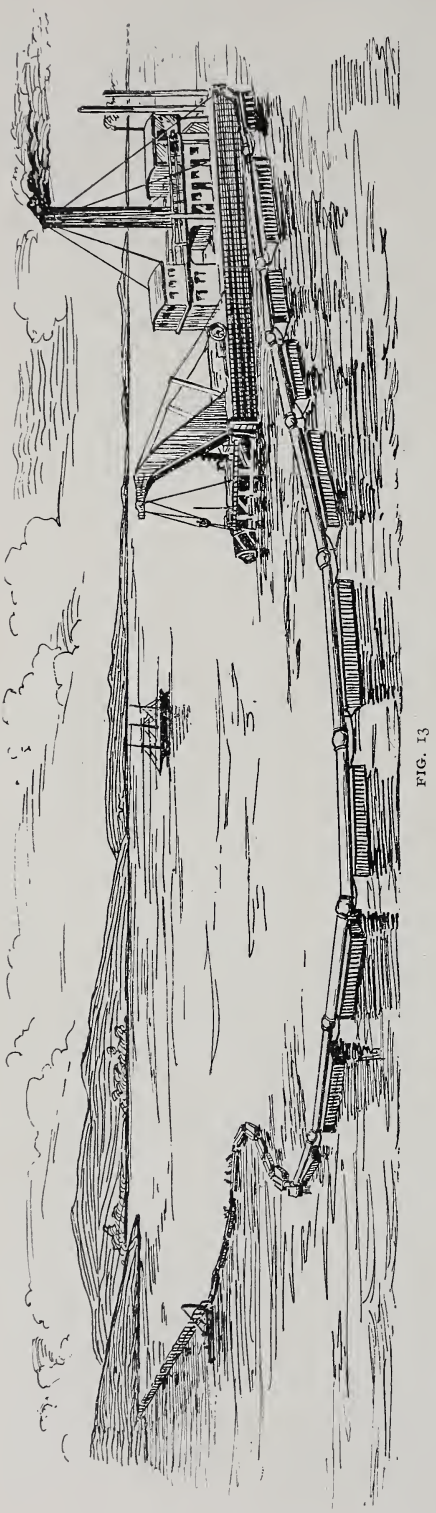


FIG. 13

and art are available to facilitate the journey. So, too, a want, fully understood, unlocks the whole bountiful storehouse of nature and art to pick and choose therefrom those things which will best satisfy the requirement. In other words, analysis must precede synthesis. Inventive acts are not spontaneous, lawless expressions of unreasoning creative force, as the patent office, courts, and legal text-book assume, but, on the contrary, consistent processes of logical construction.

In the dredger illustration an invention was traced back to its genesis. The steps and process apparently connecting problem and answer were set forth. That the steps were a mere succession of fortuitous episodes, accidentally happening in the related sequence, is, of course, unthinkable. The only alternative is that a principle underlies and governs the process.

Continuing the illustrative method, the application of the theory to a problem, the answer to which is as yet undetermined, may be helpful, even if made in a crude and tentative way. The proposition is either of universal application or it is fallacious. The same laws which govern the falling of a pin keep the planets in their orbits. There need then be no hesitation in trying this little experiment on a large problem.

No want is more urgent or more thoroughly appreciated by mechanics than a substantial reduction of the 80 per cent. or 90 per cent. loss of the theoretical heat value of fuels in heat motors. This want has been a standing challenge for the past hundred years. The advances made in other directions of human effort make failure in this hardly creditable to mechanics. The present object being solely to suggest methods of systematising inventive effort, it is not expected or intended to carry this experiment beyond the analytical stage. This problem is simply selected as one of the universally recognised and acknowledged wants, and is used only as an illustration of what is believed to be the proper course to pursue in undertaking any inventive solution, or the production of the mechani-

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cal satisfaction of a recognised want. The assumed object, in the following illustration, is to invent an ideal heat motor, that is to say, one in which the whole of the heat value of fuel is transformed into some controllable form of energy available at will. The present forms of heat motors will serve as a starting point for the analysis, more definite than the simple abstract "want." If it can be determined wherein they accord with and wherein they depart from the necessary conditions, the object is accomplished, for the proposition is that from a correct analysis the synthesis is obvious, providing the materials to satisfy the conditions disclosed by the analysis are within the experience of the analyist.

Verbal statement, particularly in the inflexible form of written language, is but a clumsy tool for analytical processes which are difficult, even when expressed in terms of mental material with all its infinite plasticity. It, however, must serve, if lamely, to indicate the suggested method.

In all heat-energy-utilising devices the range of temperature which can be transformed into useful work constitutes, practically speaking, the measure of economy. High initial and low terminal temperatures succeeding each other in rapid succession have naturally and logically formed a basal condition of heat motors. The progress of improvement has been in the direction of an increase in the available initial temperature. In the steam engine this is displayed in the development from the low-pressure, slow-speed engine of the early stages of steam engine practice to the high-speed, quadruple expansion engine of the present day, with all its refinements.

All along the line from furnace to engine the mechanical train uselessly dissipates heat energy, owing to the relatively long time which is occupied in transforming the heat into work. Heat travels by conduction with comparative slowness. The extent of surface exposed makes the heat loss in the aggregate so extremely rapid that, though starting with furnace temperature, non-conductors are necessary to limit the loss from this source. By the time the cylinder is reached a comparatively insignificant range of temperature is available. In the direction of the steam engine, therefore, the analysis need go no further, particularly as another, the internally-fired type of heat motor, suggests, on superficial examination, much greater possibilities in available range of temperature.

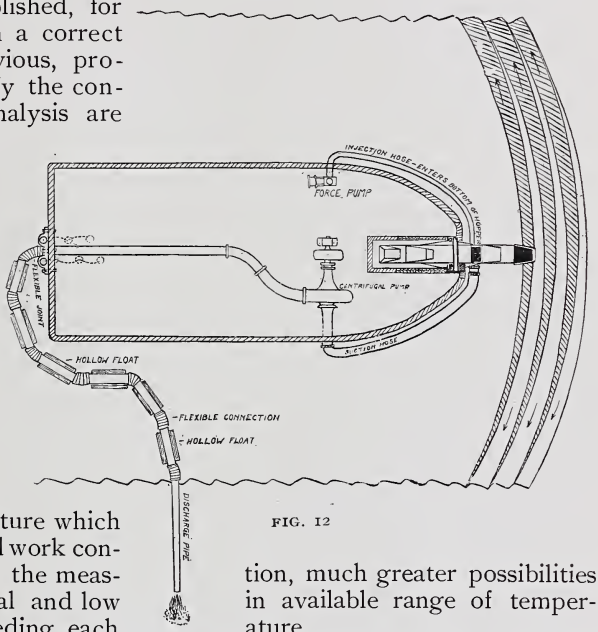


FIG. 12

It may be noted that the first ideal requirement is, that the heat be utilised with practically instantaneous rapidity, that is to say, the transformation of heat energy into a form available for useful work must be practically simultaneous with its generation.

In the type of motor under consideration the generation of heat takes place under conditions much more nearly approximating to ideal requirements than in the steam engine, owing to the diminished number of steps required for the transformation of heat into available energy; in other words, the available difference between the initial and terminal temperatures is greatly increased. Great losses are unavoidable in this

method, due to the time element before referred to, and are more directly in evidence by reason of the elimination of the steps as noted.

In the internally-fired type, the available temperature is so great that without means specifically directed to dissipating a large quantity of it, the destruction of the device by fusion would be unavoidable. The mechanical necessities of this type also demand further reduction of the working temperatures to permit of internal lubrication.

These two typical heat engines thus present diametrically conflicting conditions and requirements of heat utilisation, starting from the same point of intense heat generation. In the steam engine the heat energy is unavoidably dissipated by the long transforming process from furnace to engine. In the internally-fired engine wastage becomes necessary to preserve the integrity of the device, owing to the local intensity of the heat energy in the cylinder. In both the methods exemplified are fundamentally and obviously erroneous, as neither of them aim to utilise the whole of the generated heat-energy, but merely attempt to use a small portion of the fuel heat value.

It is commonly observable in gas engine practice that if, during an explosion, the fly-wheel be held for a very short length of time, say, a second or so, the energy of explosion will be found to have wholly disappeared, notwithstanding the fact that no expansion of the exploding gases has been permitted. This result is due to the conduction of heat through the cylinder walls, thus experimentally showing the necessity of immediate utilisation of heat energy.

Examination of the gas engine shows that it is almost diametrically at variance with natural laws, in obedience to which alone the transformation of heat into work can be made fully available, and which prescribe the requirements for the economical conversion of one into the other. Roughly stated, these requirements are:—

1st. High initial and low terminal temperatures, which, practically speaking, mean high initial pressure with unlimited expansion.

2d. Immediate conversion and storing of the energy of heat expansion into a form available for practical control and use at will.

Neither of these essential requirements are attainable in any present form of internally-fired engine. Stated in another form, the conditions necessary to the ideal explosive engine are:—

1st. Piston speed comparable to the speed of expansion due to explosion under atmospheric pressure.

2d. Cylinder temperature comparable to the temperature of explosion under highest available compression.

3d. Range of expansion always below atmospheric pressure.

4th. Temperature of cylinder at all times equal to temperature of gases therein. Or, conditions equivalent to the above, and mechanical means for transforming the energy thus liberated into available form.

Practical limitations of construction, however, obviously preclude the attainment of these necessary conditions to any considerable degree along the present lines of practice. These obvious obstacles may be grouped under two heads, viz., 1st, those relating to the piston and cylinder method of converting heat into work; and 2d, those relating to the piston and crank method of power transmission.

It is apparent that the point of explosion cannot be removed from the neighbourhood of the dead centre of motion without materially diminishing the expansion. It is equally apparent that no matter how high the rotative speed of the crank be, the speed of the piston at the time of explosion must be extremely slow so that explosive energy is largely dissipated in destructive internal strains and conduction. The expansion cannot be profitably increased, due to time losses (heat conduction) from slow piston speed.

Much higher cylinder temperature is not possible on the present lines; certainly no temperature comparable to that of explosion. The surfaces would disintegrate, if not fuse, at a lower tem-

perature. High cylinder temperature for non-conduction of heat is incompatible with low temperature necessary during charging. It is clear, therefore, that material diminution of the present losses is not to be looked for along the present lines of construction in either explosion or slow combustion type or their modifications.

Thus far the analysis indicates only unpromising directions. Still, if these conclusions are to be relied upon, much has been gained, even if of a negative character, for second only in value to knowing in which direction to seek the desired destination is knowing in which direction it does *not* lie. Rejection is negative selection.

The examination has, however, given more than negatives. It has divided our want into a number of its constituents, separately satisfiable little wants, some of which may be within the range of experience to satisfy. If so, great gain has been made. These little wants are capable also of statement in affirmative form in terms of the internally-fired engine, as follows:—

1. A cylinder adapted to permit of varying expansion commensurate with varying initial temperatures.

2. A piston in such a cylinder, sensitively mobile to initial movement.

3. Transmitting association between such a piston, and power-utilising means as will admit of the resistance being applied with increasing instead of diminishing intensity, commencing at *nil.*

It is of interest to note that these requirements are the exact opposite of the conditions which obtain in present practice and construction.

In nature or art, do elements exist the association of which will satisfy these requirements? If they do and they come within the consciousness of a logical mind directed to this want, the ideal motor will result as a simple series of logical syntheses, as naturally and inevitably as chemical reaction, providing, of course, that the analysis is correct and complete. As already intimated, the foregoing is to be considered merely as suggestive. It must be remembered that, as in the dredger illustration, each of the separate constituent wants may, in turn, be treated in the same manner as the original want, and this process may be continued till no further simplification is possible or necessary, the object having been attained.

A machine in the inventive stage, before, in fact, it has reached any stage involving even the conceptions on materials, may be reasoned about. A machine even in this embryonic condition consists of two sets of elementary constituents, namely:—

1st. Essential motions.

2d. Essential form.

The essential motions are those which, of necessity, belong to the necessary functions. They are fixed and unchangeable. The essential form is also fixed and unchangeable, and is the conceptual clothing of the motion without relation to the limitations of concrete material. For example, the necessary path involved in disintegration is a perfectly determined quantity which could be thought of or even delineated, entirely independent and apart from the future form of the excavator or the material of which it would later be made. The essential form of the excavator is equally realisable apart from its future form or material. It consists of the lines or directions of force pertaining to the essential motions.

Mechanicians who have not used this simple method of dealing with mechanical problems will be surprised at the added facility which it affords. All the difficulties and mind-racking necessities which are inherent in the constructive phase of the problem, but which are not of its essence, are avoided, or rather reserved for their proper time and order, and the problem is reduced to its true, naked, intrinsic reality. The results by this method are as certain and satisfying as geometrical demonstration. They irresistibly proclaim their truth. At this stage in the genesis of an invention two logical minds could not differ as to the solution of a given problem. It is in the work of clothing these essentials in constructive form that divergence will commence. This is due to the dif-

ference in the material mentally available to each individual.

It has been shown that problems involving the production of new mechanical devices to accomplish definite ends may be, and probably are, as susceptible of demonstration as in any other department of organised knowledge. In view of this probability, is it not high time that this important matter be taken seriously in hand? There are academies of science and of art; colleges of medicine, astronomy, agriculture, and many others, each cultivating and promoting a more or less important department of knowledge. There are also schools for the practice and acquirement of manual skill and handicrafts relating to all the important trades and pursuits. That form of human effort alone, which underlies all, and upon which all others depend for advancement, is unrepresented. That department of mental endeavour which has added most to the comfort, well-being, and progress of humanity, which has made the present age unique, it alone is left to chance and empirics.

Whether the inventive faculty be a myth or a reality, inventions are the product of some form of mental effort, and all experience goes to show that every other expression of mentality is facilitated, expanded, and improved by specific, systematic training and cultivation. Why should this not be so in the science, art, or practice of invention?

NAVAL ARCHITECTURE AND SANITATION

By J. R. Tryon, Late Surgeon-General, United States Navy

WHILE it is not necessary to bring forward all the essential reasons for the form of a ship, it is desirable to realise that, from the very nature of the work to be performed, seagoing vessels are limited to a certain shape without regard to any consideration of sanitation, and that it is this form, designed for all conditions of wind and weather, all climates and all seas, that has had much to do with the diseases of seafaring people. In a report made to the Secretary of the United States Navy by the writer while Chief of the Bureau of Medicine and Surgery, the subject of sanitation aboard ship was treated of at some length, and in it was incorporated substantially the matter given in the following pages.

The hollow, spindle-shaped body of a ship, half immersed horizontally in water, divided by horizontal and vertical partitions, with few openings connecting its spaces with the outside atmosphere and crowded with stores, implements of war and men, has its general design fixed by unalterable conditions and represents simply the structure required by the laws of nature to bring all races together and thus work out man's ultimate destiny on this globe. A human being placed within a floating body of this shape finds himself confronted with an existence for which he was not designed. His natural relation being, therefore, disturbed, there ensues a greater or less struggle in the effort to adjust himself to his surroundings. In the end there is necessarily a certain degree of individual loss which varies with the power of adaptation. This power depends to a great extent upon knowledge and intelligence through which he can alter his surroundings, approximating them more or less to nature, of which he is a part.

The study of the preservation of life from actual violence and of the destruction of life has always occupied the minds of the human race, but the subtle conditions under which health is maintained and life preserved have not, from their very nature, appealed so strongly to man's sense of self-interest. Those whose lives have been given up to the scientific study of the former consideration have been regarded as men of affairs, leaders of races, and makers of history, while those who have devoted themselves to the latter have found themselves away from the main thought of their age, and consequently more or less deprived of power to utilise that knowledge, second to none in value to mankind. This has been illustrated very strikingly in the history of the sea. Up to a very recent date no ship had ever been constructed in which the question of the health of the crew had been scientifically considered in the design itself, and there have been few after construction in which intelligent effort has been directed to the preservation of health. The great idea in all time has been to sweep the sea,—to have dominion over the waters. For this purpose ships have been built as mere engines of war, and with but little consideration for the fact that the most indispensable mechanical instruments are men themselves. Ships were few, and represented much time and money; men were many, and could be easily replaced. And thus for hundreds of years much more anxiety was exhibited

in preserving arms from rusting and cordage from rotting than in considerations affecting the health of crews.

The story of shipbuilding, so far as it is related with any definiteness, begins among the people of the Mediterranean. The Phœnicians desired to navigate the sea for commerce; and, later, the Greeks and Romans for trade and conquest, for supremacy as nations. They studied the problem in their own way, having due regard for the fundamental considerations heretofore presented. On smooth waters where a vessel with sails might be becalmed for many days together, necessity determined that the principal instruments of navigation for vessels of war should be oars. Oars would allow rapidity of motion and enable the attack on the enemy to be swift, sure, and complete. Naval architecture then centered around the arrangement of oars, and every possible expedient was resorted to to give each ship the greatest possible number. As there was one man to each oar, and as every additional biceps meant increased power, all available space was occupied, so that when a ship was in motion there was not room between decks for another human being. This necessity for crowding vessels of war with men has existed in all ages, and has been one of the greatest factors in determining the prevalence and intensity of disease. At first it was to get the maximum of propulsive power, afterwards it was to work guns and manage sails, and now it is to shovel coal and grind out shot, the purpose always being to have a greater force than the adversary at that supreme mo ment which is the summit of opportunity in a fighting ship.

In that day the problem was simply to find the smallest space in which a man with an oar could work and then shape the ship for the maximum speed and efficiency. In those early days there was no upper deck, and consequently the supply of fresh air was unlimited, though the exposure to sun and spray was great. But as naval warfare became more complicated and its requirements better known, an upper deck became necessary to strengthen the ship for the use of the ram bow, to furnish a commanding position for the fighting men, and to give some protection to the rowers. But this deck, even when Rome was at the height of her power, was never complete. Gangways extended from the bulkwarks toward the mid line, leaving a wide open space surmounted by a hurricane deck, between the supports of which an awning could be placed for protection against the weather. Below the rowers was the deck covering the hold, which contained cisterns of drinking water, and much bilge water. All these vessels were built of timber never allowed to season before being used in construction, so that it might be bent into the necessary shapes. As a result the seams were continually opening, and, in spite of calking and application of tar, the mass of bilge water required the constant use of buckets in bailing or of a machine consisting of an Archimedean screw worked by some sort of treadmill.

In the typical warship of ancient times there were placed 174 men, arranged in three tiers, in a rowing space of about 15,000 cubic feet. Below them was the hold, with its constantly renewed bilge water, and above was the sky, which could be seen by those rowers in the upper bank. Then there was the mast with the square yard and sail, and on each side the many oar ports, closed against the water by leathern bags. Such were the war vessels of the ancients, and in all essentials of the whole world until the fourteenth century, when the application of magnetic attraction in a practical form to purposes of navigation inspired mariners with confidence and made it possible for them to commit themselves to the trackless ocean without fear. These ancient war vessels, constituting the navies of the world, show from their very construction and from the scope of their work that they were not the homes of such diseases as have made the account of many cruises of more recent times one of suffering and death. They were calculated only for a tranquil sea, and seldom ventured far from shore or quitted ports at those seasons when hurricanes or tempestuous

weather were liable to endanger their safety. Fitted with flat keels and constructed with rather flat bottoms, they were frequently drawn up on shore, and were at no time the permanent homes of men. With enemies near at hand, naval fights were soon precipitated, and after victory the conveyance of troops was alone necessary for the complete subjugation of the most powerful and remote territories. Indeed, for purposes of war, the soldier and the sailor were often the same, as shown in the invasion by William the Conqueror, whose ships were burned as soon as he landed on the British coast.

But the mariner's compass and the introduction of cannon on board ship made a wonderful change. Then the nations of western Europe filled the Mediterranean with sailing vessels devised for voyages on the ocean, and oars finally gave place to sails, though, as a rule, still holding their own on vessels designed solely for use in that landlocked sea. With the mariner's compass and the introduction of cannon begins the story of sea voyages of discovery and the history of the long struggle with diseases at sea. Prior to that time naval architecture reached the limits of perfection in a few years, so that countries that had neglected maritime pursuits were able, on the impulse of the moment, to place themselves on an equality with the strongest sea powers. But gunpowder and the magnetic needle, when the knowledge of them became common, augmented in a wonderful manner the properties of ships, whether for war or for commerce, changed their construction in a great degree, and made them the permanent homes of men. From that time the scene of maritime greatness shifts gradually from the smiling Mediterranean to the tempestuous Atlantic, and naval architecture moves from vessels with oars to ships with sails. The galleon superseded the galley, and the day of ancient ships was past. Madeira, Cape of Good Hope, America, and the route to the Indies are names marking this new era in the history of the sea. Shortly after these discoveries the introduction of cannon on shipboard became general, and it was in 1500 that Descharge invented port-holes.

The navigation of the Atlantic and the use of cannon, with the introduction of port-holes, led to ships of greater size, higher sides, and many decks. Decks, on the abolition of oars, ceased to be open along the mid line, communication being maintained by square hatches, which were closed in bad weather. The questions of naval architecture now centered on the greatest amount of sail and number of guns. Toward the close of the sixteenth century Spain had vessels of three decks, carrying over 100 guns, and that country was followed, in the seventeenth century, by Great Britain, which eventually built ships carrying 120 guns and 800 men.

The era of sailing ships of war begins, then, in the fourteenth century. It continues for nearly five hundred years, and its story has many chapters of suffering and death, incident, in great part, to a faulty construction of the vessels themselves. These old ships were built of wood and had holds of great depth, that they might sail close to the wind. Guns were placed even on the lowest deck, and for many years the port-holes on that deck were within 16 inches of the water. Communication between decks was maintained by hatches, those leading to the hold being closed except when it was necessary to break out stores. The lowest part of the ship was, therefore, a perfectly dark and unventilated space, and, as the bottoms of vessels of war were not coppered until after 1779, was never free from a considerable amount of water. For many years the air in this part of ships would at times be so foul as to stifle men before they could be drawn up; and, next to drowning, the most common accident peculiar to a life at sea was suffocation from foul air.

The necessity for visiting the hold was not infrequent, for the pumps were apt to be clogged with filth, and some one had to venture down in the well to clear them. Besides, until 1815 all drinking water was carried in casks, and each day a sufficient number of

these had to be hoisted for that day's supply. At sea this was frequently the hardest and most dangerous duty of seamen. Next to the violent pressure on the abdomen while lying on yards in furling sails, it was believed to be the most potent factor in the production of hernia. It also was the cause of many other injuries, and exposed the man each day to poisonous and at times irrespirable air. In the hold, until this century, were also carried gravel, sand, or other earthy substances for ballast. This retained putrescent matters and was a prolific source of disagreeable odours and disease. In a correspondingly short time the lack of ventilation and the presence of decomposing material and moisture caused more or less decay in the various stores and even in the timbers of the ship. This condition of things existed on every vessel of war, and was a marked local cause of discomfort and disease. The utmost distress would at times arise from the decay of water casks on long voyages and in remote parts of the world, where they could not be replaced, while drinking water carried in imperfect casks and exposed for months to vitiated air would generate and absorb various poisons and cause many deaths.

The ships of this period were, in a general way, much like those of later times. Decks communicated by hatches and contained tiers of ports for guns. To work the guns with which each vessel was burdened, men in great numbers had to be provided, so that the living spaces were very much crowded. Ports were closed in bad weather for days together, the lower tier being rarely open under any circumstances. As there was at such times no arrangement for the admission of light, the darkness between decks necessitated the use of candles, which further vitiated the atmosphere. Hatches were frequently not placed in line, one below another, so that the lower decks were often deprived to a great extent of the slow vertical exchanges of air from difference of temperature. Openings on the upper or spar deck were covered in time of torm, thus shutting off all communication with the outside air. When it is added to this that in the largest navy of the world the supply of soap and fresh water was very limited until 1810 or 1815, and that but few changes of clothing were provided, there is presented a picture of a dwelling place of which the details can be safely left to the imagination.

Under such circumstances it can be readily perceived that the great dangers of a seafaring life were resident in the ship itself, and that these would increase with the size of the vessel, the multiplicity of decks, and the number of the crew. The larger the ship, the greater the amount of sickness and death. This is well illustrated in the expedition of Hosier to the West Indies in 1726. His fleet consisted of seven ships of the line. It is stated that before his return he buried two crews for each vessel, the causes of death being scurvy, fever, and intestinal troubles. Though this is, perhaps, the most disastrous instance of the baneful effects of sickness in any navy, history supplies us with many others in which naval expeditions have been entirely frustrated by the force of disease alone. Among these may be enumerated that of Mansfeldt in 1624, the Duke of Buckingham in 1625, Wheeler in 1693, the expedition to Carthagena in 1741, D'Anville in 1746, and the French expedition to Louisburg in 1757. But prior to all these may be mentioned the invasion of France by Henry V. in the early part of the fifteenth century, in which, owing to some delay in the embarkation, his army was reduced by dysentery from 50,000 to 10,000. Nor is the story of Anson to be forgotten, who, in a cruise of a little more than three years, buried four-fifths of his crew and had lost 200 men within five months after his departure from home. It was on this expedition that the captains and surgeons of the squadron represented to the commodore the frightful condition of the air between decks, and the absolute necessity for some change, that the men might be allowed to breathe and that the ships, which were so deep in the water that their lower ports could not possibly be

opened, might be relieved to some extent of the stench, increased by the large number of sick. As a result, six air scuttles were cut in each ship in such places as the strength of the structure would allow.

Sir Richard Hawkins, who lived early in the seventeenth century, mentions that in twenty years he himself had known of 10,000 deaths from scurvy alone, and it is stated that in 1739 the vessels in the squadron at anchor at Spithead stunk to such a degree that they infected one another, and that the men became so dangerously ill from want of air that they were put ashore to recover their health. The British Channel fleet in 1780 was so overrun with scurvy and fever that it was unable to keep the sea after a cruise of only ten weeks. During that year there were transferred from the fleet to one naval hospital over 5000 cases of continued fever and nearly 1500 cases of scurvy. In the same year, in the British West Indian fleet, having a strength of 12,109 men, the mortality was 1518 from disease alone, and but few of these deaths were due to yellow fever. It was in this same century that the Spanish ship *Oriflamma*, on her passage from Manila to Acapulco, a voyage, in those days, of nearly six months, was found at sea with her whole crew dead on board.

Now, while it is not intended in this partial enumeration to convey the idea that all this sickness and death at sea were due entirely to a faulty construction of the ships themselves, it is very evident that much of it was due to that cause alone, and that nearly all of it was to some extent inseparably connected with it. During all this period, up to the beginning of the present century, the great diseases of the sea were fevers, scurvy, dysentery, and diarrhœa. While scurvy, on account of its great prevalence, its disgusting characteristics, and its practical abolition from the sea in 1796, has, in connection with its great mortality and its association with some of the most remarkable expeditions in history, attracted the eye of the whole world, typhus fever has been a more grievous and general cause of sickness and death. No one denies that the latter finds its cause in air contaminated by foul exhalations, derived in great part from the living human body, and incident to that crowding of human beings in filthy and contracted spaces.

If citric acid be regarded as a preventive of the one disease, soap properly employed may be considered as almost of equal force in the other,—the one remedy dating its general use from about 1796, and the other not making its influence felt in the navies of the world until some years later. But the degree of cleanliness, dryness, and ventilation on board ship has had a direct relation to both diseases, and during their prevalence it was a subject of common observation how much more sickly than others some ships were in the same squadron, though supplied with the same diet. While every one admits that scurvy is a disease depending fundamentally upon the absence of certain salts in the food, there is no question that its prevalence and intensity bore a marked relation to confinement in bad air, indolent habits, and depression in spirits, and though not strictly a disease of the sea, found something in the conditions of ship life outside of the question of food conducive to its propagation. As an example of this, it is stated that as Portchester Castle could not accommodate the French prisoners in 1798, a number were removed to a ship in an adjoining creek, where many exhibited scurvy, though the diet was the same on the ship as on shore, and at the latter place the disease did not appear. Time and again this trouble has occurred on ships when men in garrison have remained free from it, though living on the same diet. In all these instances lack of dryness, cleanliness, and ventilation, and also lack of exercise and recreation, have been a sufficient exciting cause.

The magnetic needle made long, continuous voyages at sea possible. It incited man to build huge wooden structures that could withstand the assaults of the ocean itself, and, bearing cutlasses and guns, could sweep the sea and carry fire and sword into distant lands. For

a navy consists of all the ships of war belonging to a nation, together with their officers, men, and equipment. It is that part of the fighting force of a country which operates on the water, guarding its coasts and protecting its foreign interests. It consists fundamentally of a number of movable floating forts of limited size and shape, with a propulsive power resident in themselves. Of all, probably the most indispensable mechanical instruments are men. And yet for hundreds of years but little thought was given to their care and preservation. Many experiments were made looking to the prolongation of the life of timber, but in regard to that of men the State was either careless and indifferent or too ignorant and economical to seek knowledge. When at last changes in naval architecture did occur, they were based primarily upon the preservation of ships and stores. In all attempts to introduce inventions designed solely for the improvement of health there was generally a more or less obstinate resistance, due to some extent to a superstitious attachment to long established practices and a greater or less contempt for all kinds of innovations.

It is true that necessity from almost the beginning of seagoing sailing vessels caused the introduction of wind-sails, which distributed air when it was least needed to only certain parts of the ship, never reaching the hold, and which were apt to be neglected on account of the difficulty in getting them up and care in trimming. Besides, the wind-sail could be employed only in mild weather, and was not always of use then, for near the equator, where fresh air was most needed, there would be many days of complete calm. There were times, too, when for days the atmosphere between decks had been stifling, that wind-sails would carry down to sleeping and probably sick men draughts of cold air, well calculated to add troubles to those already existing. It was not, however, until the eighteenth century that the air we breathe began to be intelligently investigated, and ventilation came to be seriously considered. We hear, in 1734, of Desagulier's machine for promoting ventilation by aspiration and propulsion, and at about the same time of Hales's ventilating apparatus, which consisted of the employment of wooden bellows worked by hand, and of Sutton's method of aspiration by heat, in which the supply of air for the galley fire was taken from the hold, to which fresh air was supplied by tubes leading from the upper deck. In all these methods the arrangements were either cumbersome and crude, or considered open to other objection, and none of them was generally employed.

Though the need of ventilation between decks was recognised throughout the navies of the world by those having charge of men, to naval architects the evils arising from the presence of bilge water and foul air in the holds of ships were chiefly connected with the durability of material. It was found that the moisture and lack of ventilation tended to the formation of mould and the production of certain combinations destructive to the frames and planking below the water-line. In the attempt to obviate this the different ventilating appliances were employed to a greater or less extent, the Hales apparatus receiving more general attention than the others. This invention was first tried in 1753 and remained in use for nearly half a century. In addition to increasing the durability of the ships, it promoted the health of the crews in a marked degree. The Earl of Halifax, comparing the mortality in the ships on the coast of Nova Scotia, stated that the deaths in ships which were not ventilated were, in comparison to those that were ventilated, as 12 to 1. The apparatus was not, however, kept in constant operation, and, moreover, was liable to get out of order on account of a lack of simplicity in structure. The admirable invention of Sutton, which was tried on a number of ships with very good results, failed in general adoption because of the inertia of those in power and the expressed reason of fear of fire on shipboard it strangely induced. Nevertheless, these inventions emphasised the good effects of fresh air upon

the health of crews, and ultimately stimulated, to some extent, the introduction of air tubes and automatic ventilators. But about this time the system of shipbuilding, which had for so many years been obviously defective, began to be improved. As ships were not strong enough to bear the strains to which they were subjected without departure from their original lines and without in a relatively short time admitting an undesirable amount of water, inventive minds had long been seeking some marked improvement in construction. This found expression in 1806, when Sir Robert Seppings undertook, among other marked changes, to fill in the spaces between the frames under the flooring of the hold with pieces of wood, calked and pitched, leaving the higher spaces between the frames in communication, through the inner and outer planking of the ship, with the open air. These changes in construction, though undertaken to add strength and durability, are most important when considered in relation to proper sanitation. The cavities under the floor of the hold had long been the receptacles of every variety of filth and vermin. They had been responsible, for hundreds of years, for much of the foul air and offensive exhalations. Their obliteration and the creation of channels to the open air were allowed to supersede all other methods of ventilating the hold and did inaugurate an improvement in health at sea that cannot be overestimated. This change, with the use of copper covering for the bottoms of ships, made a marked alteration in the condition of the hold, improving the air to such an extent that it ceased to be a cause of death by asphyxia.

Shortly after this a new method of ballasting vessels was introduced. The weight of iron tanks, each containing two tons of drinking water, was substituted for the sand and gravel usually carried, and which would remain undisturbed for years. Though the tanks also replaced the lower tier of casks, the economy in storage was so great that the daily issue of water became more liberal, and, therefore, personal cleanliness more possible. Another result of this important change was that injuries at sea became less frequent, for water for daily use could now be supplied by force pump and hose, the necessity for hoisting casks no longer existing. The improvement in the storage of drinking water and the other changes indicated caused a marked diminution in the prevalence of continued fevers and lessened, in a great degree, the mortality formerly incident to naval life. It was also about this time that glass bull's-eyes were inserted into decks and ports for the admission of light in bad weather. This diminished the use of candles in the daytime and lessened to that extent the vitiation of air and the consumption of oxygen.

With all these changes may be mentioned one that was far from being unimportant. Formerly the place appropriated for the sick in a ship of the line was forward on the lowest gun deck. Undoubtedly such a situation for many years on account of the dampness, lack of air, and general inconvenience, was in itself the cause of many deaths, but not long after the beginning of this century the sick bay was located on the deck above, where, with better air and easy access to the head for necessary purposes, a great improvement in results was quickly noticeable.

It is worthy of remark that the subject of sanitation on shipboard seems then at last to have occupied to some extent the minds of those in authority over the naval affairs of the world. The severe lessons of so many centuries of disease and death were at last producing effect. In this connection it may be mentioned that it was in the early part of 1805, that surgeons in the British navy were given the same rank and pay as their brethren in the army, and that thereafter the general character and professional skill of medical officers in that service became much improved. Men who had been allowed to enter the navy were required to mend their medical education or be expelled, and candidates for examination were possessed of more extensive information, as the rank and respectability which had been

assigned the corps attracted good material. In the year following this change the public instructions issued to naval commanders in the British service contained for the first time directions relating to ventilation and cleanliness. Stricter discipline in matters relating to health, improvements in the medical service, and those changes indicated in naval architecture promoting dryness, ventilation, and cleanliness on naval vessels caused a rapid decrease in sickness. Two ships now were more than equivalent to three formerly in point of efficient service. Naval hospitals were no longer crowded to their full capacity, for scurvy had disappeared from the sea, and ulcers and febrile disorders had become less frequent and violent. In the British service this decrease was very striking, and throughout the world the story of the sea had ceased to be one continuous chapter of sickness and death. Much, however, still remained to stimulate effort and demand improvement. Continued fevers, intestinal disorders, rheumatic troubles, and particularly pulmonary complaints, were still too common, and preventive medicine had still many problems to unravel, some of which, however, remain to this day unsolved. Every ship sailing the ocean soon contained many rotten timbers, all attempts at ventilation had met with only partial success, and men still slept crowded together in small spaces, as they do now, and as they probably will do for all time at sea.

It was in 1823 that the prevalence of pulmonary and rheumatic troubles and the too common appearance of malarial disorders and adynamic conditions, especially in the tropics, called marked attention to the too frequent use of water on the decks of ships. It was the routine, and remained so until a very recent date, for men to begin scrubbing and holystoning decks at about 5 o'clock in the morning, and, with a short interval for breakfast, to continue that occupation for about five hours each day. Seamen were compelled to work with bare feet in tons of water on the spar deck for over two hours each morning, even when the thermometer was below the freezing point, and then were allowed to go to breakfast in wet clothes. After breakfast the lower decks were deluged with water and holystoned for an hour or more. Between decks the outlet for this water was into the hold by two small scuttle holes cut close to the ship's side. Through these openings there passed each day this mass of water, sand, vegetable and animal matters between the ship's side and lining. It was a common sight in those days to find men after all this exertion sitting around on wet chests, or, after a night's debauch in that time of grog, sleeping in wet canvas clothes on the deck they had just scrubbed.

The construction of a ship is such that, with this treatment, decks can never dry, and in spite of the so-called "drying stoves" then in use, they remained wet until again subjected to the water treatment. In this routine again becomes apparent the tendency in all times to subordinate health to appearances. The rivalry between commanding officers to have the best-looking ship was the mainspring of this action. While the decks were kept white as snow, water and filth were run into the hold, where it was generally allowed to remain, its removal presenting no external mark of approbation until the increasing sick list or odour demanded its removal. Not only was the dampness between decks exceedingly dangerous to health, but the accumulation of filth in the hold hastened the decay of timbers, and especially in the tropics, where the putrefactive process runs its course most rapidly, made each ship a ready home for various infectious diseases. It has been well authenticated that if two ships shall happen to be cruising together, the one having the greatest amount of water between decks will have the largest sick list. This was especially noticeable in the days of scurvy, but is also true, it seems, for all times.

It was at this time that the Perkins ventilator received its most extended trial. The Hales ventilators had gradually succumbed to the common wind sail, as they were thought to occupy too

much space and demand too much time and manual labour to work them. The Perkins ventilator consisted of two connecting tanks, half filled with water, placed diagonally across the keelson and connected by valved tubes with the air of the hold and that outside. As a ship would pitch or roll, the water would fall in one and rise in the other, and thus air would be taken into one by aspiration and forced out of the other by compression. This automatic arrangement appealed very strongly to the scientific minds of the service and was of no small use. At any rate, this ventilator and the wind sail were the best ventilating appliances in use on ships at sea in 1823. They were both of little force in the long days of calms in the tropics, and were generally deficient in continuousness and certainty of action.

The hold has always been, and must ever continue to be, that part of a ship requiring continued care and attention. Being the lowest portion of a vessel, it must ever be there that gravity will carry much refuse animal and vegetable material. It is also that part of a ship which is ordinarily in the dark and where dirt and filth remain out of sight, and, for the most part, out of mind. It has presented the most difficult sanitary problems on shipboard, and has been the greatest cause of infection and death. In spite of its position and history, probably no wooden vessel has ever been built in which the most perfect ventilation possible has been sought in the very construction of the ship itself. Ordinarily a vessel has been built first and then some method of ventilating the hold devised afterwards; or when any such system has been considered in the design, it has been poorly carried out or allowed to be defeated by simple mechanical difficulties. Naval architects during all the days of wooden ships thought, for the most part, of the vessels themselves, and but little, it would seem, of their crews, except in a general way. They were not medical men, and very naturally followed the lines of their own profession. It was seldom that medical minds were brought to work with them, and, therefore, changes in structure for sanitation were caused very slowly by a general diffusion of knowledge on such subjects.

All wooden ships had an outside and inside planking fastened to the frames, which were, in turn, fastened to the keel. The keel would then correspond to the vertebral column, the frames to the ribs, and the planking to the intercostals. The spaces between the frames communicated below with the timbers or covered drainage channels on each side of the keelson, and it was here that the foul air would naturally leave the hold and find its way up between the outside and inside skin of the ship to the outer air. These natural uptakes were uninterrupted by the decks, which rested below on the shelf running horizontally the whole length of the ship and had the waterways above. Any opening through the waterways or shelf into any space between the outer and inner planking would, therefore, connect the decks with the hold. Unfortunately, this was not infrequently done under the idea that the heated air between decks would pass up along with that from the hold into the outer air. But the motion of the ship at sea would often pump the air from the hold among the crowd of sleeping men. Besides, the natural uptakes for the air in the hold were made nearly useless by obstructions formed by sills of gun ports and by blocks put in between frames to give stability to ringbolts used in working the guns. The sill of each gun port rested on the ends of two frames and thus completely occluded three channels, and as the ports of the upper tier were never directly above the lower, but between the port sills in large ships, obstructed the majority of all the communications of the hold with the outer air. Each chock let in for the ringbolts obstructed still another channel, and so a number of cul-de-sacs were formed where decayed wood, mould, and accumulation of filth made it easy for the ship herself to become diseased and almost impossible to disinfect her and free her from the plague. This condition of things, in a greater or less degree, ob-

tained in all wooden ships, whether in the days of sail or steam.

Steam began to be used on naval vessels as a propulsive power about 1822. With it begins a new era in naval architecture and a most wonderful change in the life of the mariner. However, until a very recent date this power was employed as only auxiliary to that of sails. This was due at first to an incomplete knowledge of the capabilities of the newly discovered force and to the lack of sufficient ability to construct boilers and machinery suitable for its manifestation. Afterwards, as the knowledge of steam engineering increased, sails were retained on account of the tendency of all ages to cling to old ways and customs and to resent the triumph of the new over the old. Machinery, boilers, and coal were put into sailing ships to be carried, for the most part, as so much cargo or ballast. Sail power remained unreduced and the battery practically unchanged. As a result, the crowding on board ship was considerably increased. Not only was the extent of the living space much reduced, but the number of people greatly multiplied by the necessary stokers, firemen, machinists, and engineers. The capacity for carrying stores was, however, also diminished and the number of days consumed in voyages much reduced. The mariner's compass had pointed the way across trackless oceans for four long centuries, and man had slowly and painfully followed, the sport and plaything of every wind and storm.

Steam brought with it both speed and precision, gave motion even to the long days of calm, and shortened in a wonderful manner the unnatural separation of man from the soil. Ports were thus visited more often, fresh food became more common, and recreation and exercise not incident to life at sea more frequent. However, with the greater crowding of human beings in ships, no additional means were provided for an increased supply of fresh air between decks. Machinery, boilers, and coal bunkers also rendered the hold more difficult of access for cleaning, and added oil, grease, cotton waste, and other filth to its contents. Concealed and filthy places in the lowest parts of ships became more common, the odour of bilge water more general, and the contamination of sleeping quarters more pronounced.

In the days of sailing vessels work was, for the most part, performed on deck in the open air, but now a considerable portion of the crew was destined to work in the engine rooms and fire rooms in comparative darkness below the water-line, exposed for hours to temperatures at times exceeding 160° F. This change in the life of seafaring people has brought with it its own problems, and presents to-day one of the most serious questions in ship sanitation. No life could be more unnatural than that of the coal-heaver and fireman on a ship. Working laboriously in confined spaces, subjected to great heat, and breathing an atmosphere containing quantities of coal dust and other impurities, many of them suffer from sudden exhaustion, organic heart trouble, or a premature diminution of vital powers. As the use of steam has increased and engines of higher and higher power have been devised, this class of men in a ship's complement has increased and this subject has assumed greater and greater importance and become more and more worthy of a consideration it has never received.

When steam was first applied to vessels of war, the energy was exerted upon the water by paddle-wheels. At that time the engine-room hatch was naturally in communication with the berth deck, from which a considerable quantity of foul air was drawn by the current ascending from the fire room. When the propeller came into use, though a slight saving of space resulted, it was considered necessary in many ships to introduce bulkheads between the engines and the men's sleeping quarters. As a result, the sleeping quarters became exceedingly warm, and this, with the accumulation of foul air, rendered sleep debilitating and lessened the power to assimilate food. In many ships the discomfort was so very great that a considerable number of men would, when-

ever the weather permitted, resort to the spar deck and sleep in the open air. This, to a certain extent, relieved the crowded condition of the lower deck, but subjected many of the crew to the excessive dampness, dews, and malarial and other influences incident to many climates. In damp weather, and also at times in clear, awnings were spread in port to prevent water from reaching the berth deck through the hatches or to protect the men sleeping in the open air. This diminished the movement of air between decks, and thus added materially to the closeness of all parts of the vessel. In addition to this, a ship with anchors down swings, on account of the excess of length over breadth, with wind and tide. It, therefore, happens that, even when smooth waters allow the air ports to remain open, the living space is generally deprived of the advantages of the natural cross ventilation considered so necessary in the hospital pavilion of to-day. This same wind, acting on a ship as if it were a vane, covered the whole vessel with the odour of fecal matter from the "head" at the bow, which, from faulty construction, no means of flushing, and very frequent use, it was practically impossible to either clean or disinfect. It is not desired to exaggerate this picture, so common in the days of sailing ships and so intensified in the wooden steam vessels, now passing away. To accommodate the crew, hammock hooks were placed 14 inches apart, and the air space for each man on the berth averaged about 70 or 80 cubic feet. Ventilation depended upon a row of 7-inch air ports on each side, so near the water that, as a rule, even in port, they had to be closed; hatches in the deck, closed or hooded in very bad or wet weather; wind sails, frequently not used at sea and untrimmed or without wind in port, and an occasional metal ventilator turned by hand and frequently placed so low as to be excluded from the uncertain breezes. Much of this situation was, in the absence of artificial ventilation, due, as has been shown, to the fundamental shape of the ship itself.

The problem in an abstract way reduced itself to the ventilation of a space by a few openings in the ceiling or top with the natural condition of the outside air colder than within, and with the occasional aid of an air shaft, cowl, or wind sail. The mathematics involved, the method of computation, and the usual deductions are well known. They have, however, been often misleading when applied to ships. The amount of air going into a space in relation to that coming out is by no means a measure of the general circulation in that space, and while it is true that under ordinary circumstances cold air falls and warm air rises, the result has to be interpreted in accordance with other circumstances. Some of these circumstances are that the deck overhead is broken by numerous large beams, which tend to imprison the foul and ascending breath and other exhalations of the sleeper swinging a short distance below, and that sides of ships are divided by knees and numerous projections, and present many corners. With but little motion in these places, the diffusive power of air and the exchange by gravitation are small when compared with its tendency to seek an opening or exit along the line of least resistance.

As a result, the measure of the quantity of air supplied to a deck by a wind sail, ventilator, or cowl and of that leaving by an adjoining hatch are no true indication of the amount of fresh air that is being utilised. The colder air does not become generally diffused, its steam lines and flow are well defined, and the larger quantity moves to the nearest and largest exit. The eddies produced are not extensive, though the draught is marked, and, at times, dangerous. A short distance away the vitiated, imprisoned air continues its slow exchanges, warmed by the heat of the ship and respiration, and loaded with carbon dioxide and animal exhalations. The same conditions also apply, in some degree, to simple exchanges through the hatches, the vertical circulation not being a true measure of the lateral extension. But even this important movement becomes much diminished when decks are multiplied and

when, as has often happened, the lower hatches are not placed directly below those above. Air ports would naturally, when open, assist materially in producing a general diffusion, especially when a disagreement between tide and wind in port caused the ship to assume the diagonal of the parallelogram of forces. Unfortunately, however, either the splash of water or the draught of cold air on individuals crowded against them has under such circumstances generally necessitated their closure. Besides, these ports, in spite of the packing employed, frequently leak, and drip cups have to be provided for the water at sea. Such cups are usually connected with the hold, from which the odour of the bilge and vitiated air have found a ready entrance.

This situation existed at a time when the knowledge of preventive medicine was increasing rapidly, and the microscope, in intelligent hands, was gradually substantiating the germ theory of disease, and leading to a better understanding of the conditions favourable to its propagation. Computations of the amount of carbon dioxide and organic matter in the living spaces became common, and increased attention was thereby directed to the necessity for improvement. That the problem was either difficult of solution or its importance not properly recognised by those in authority, is shown by the large number of different appliances contrived, and the few ever adopted. In the majority of these, heat itself was naturally utilised, as it was not only on hand, but recognised as the great cause of the natural circulation of air everywhere. Improvements were, however, also made in wind sails, cowls, and various ventilators dependent upon natural forces, and much attention was given to the arrangement of uptakes and downtakes. The most noteworthy expedient, however, was practically the revival, after more than a century, of Sutton's idea. This scheme, which was applied to not a few ships in foreign navies, involved the extension of the jackets of smoke pipes downward in an expansion over the boilers. Air tubes were conducted from various parts of the ship to the space thus created, through which the hot air from the fire room ascended. Communication was also made between the limbers and the ash pits. In another system jets of steam were used in tubes to create an upward draught. But none of these changes became general; and the old conditions continued, in spite of the most urgent representations of the danger and distress. Even the old routine of submerging the decks in water, almost daily, remained, and no amount of advice and disastrous experience prevailed against it. Typhus fever was not unknown, various other contagious diseases became too common, and yellow fever found a congenial home.

A fair illustration of the condition of these wooden steam vessels, some of which still remain, is found in the history of the *Plymouth*, of the United States Navy, as late as 1878-79. This screw corvette was first commissioned in 1869, and, therefore, fairly represents the faults in construction belonging to this entire period. In four years several hanging knees and considerable portions of the decks and outer planking were renewed on account of decay. This is an example of the methods of repairing at that time, and of the difficulties a complicated wooden ship presented in this line. Such parts as were open to inspection received much attention, but the repair of those concealed was largely dependent upon chance or an exhibition of weakness of structure. During the succeeding cruise much time was spent in warm climates, and cases of zymotic disease were reported in every month of the year, the most marked occurring in a captain of the hold, who exhibited cramps in the legs, nausea, vomiting, and fever. In a short time the *Plymouth* was recognised as a very unhealthy ship, and in 1878 she became infected with yellow fever. Removal of crew and stores, repeated fumigations, applications of lime, freezing, and paint were resorted to, but on her return to sea, in 1879, the disease reappeared without possible reinfection. Then borings and cuttings of scuttle holes dis-

closed cul-de-sacs bounded by decayed wood, covered with fungous growth and filled with decomposing filth and refuse matter. No amount of cleaning or fumigation could reach such places. Such spaces have existed in all wooden ships since the galleon first appeared, and, under certain circumstances, the results have been practically the same.

The introduction of steam on vessels of war was ultimately destined to exert a marked influence on the prevalence of intestinal disorders. The history of diarrhœa and dysentery is one of the dark chapters in naval life, and outside of the question of food, was largely dependent upon the quality of drinking water in use. During the whole period of sailing vessels, and of steamers before the use of distilled water became general, it was not unknown for a large number of the crew to be attacked with these diseases shortly after a supply of water had been obtained from the shore. The questions of storage and supply had always occupied much time and necessitated much care. In many parts of the world water boats could not be obtained, and the necessary supply was either brought off in the ship's boats or floated off in casks. This work, in tropical climates, and often in the heat of the sun, was, outside of the question of injuries, often productive of unfortunate results. Besides, even after so much work and exposure, the water was frequently far from portable, and would seek its own purification by fermentation and putrefaction.

The introduction of iron tanks, the appreciation of a greater need for cleanliness, and the employment of a more careful and exact examination into quality caused a marked improvement, but even after such changes there were at times more deaths from dysentery on one vessel in certain localities than occurred in the whole navy after distillers were generally introduced. This innovation not only abolished the use of casks, but promoted personal cleanliness, improved the condition of the hold, and allowed more room for stores.

Probably the most striking event in the history of naval architecture is the substitution of metal for wood as a material for ships. The *Monitor*, in the days of the American Civil War, not only demonstrated the advantages of iron over wood for purposes of war, and revolutionised the methods of naval architecture, but also furnished a marked example of how sanitary ideas in shipbuilding have had their birth. In the fight between the *Monitor* and *Merrimac* it was found that there was not sufficient air in the turreted steamer for the crew, and that the suffocating gases generated by the explosion of gunpowder found their way below and rendered it practically impossible for the men to work. Necessity, therefore, compelled the introduction of some apparatus for artificial ventilation. The old methods, in vogue for hundreds of years, had been retained, even under the new conditions, and but for the striking exhibition of direct interference with fighting capacity, would have remained for many years longer. In the *Monitor* was placed a rotary blower, worked by steam, and practically similar to the Desagulier wheel of the preceding century. Air was thus drawn from one-half of the steamer through a system of pipes and forced into the other. Various changes were made in later ironclads of this period. In some the air was drawn down the turrets and forced throughout the vessel, thus rendering them more than ever liable to suffocate the men below in battle, while in others the supply was obtained through armoured cylinders and forced out through the turrets.

It was in the early ironclads that a peculiar disease developed which, being confined to those vessels, was soon designated ironclad fever. In this affection the initial symptoms were much like those of typhus, but in a short time severe occipital pain was followed by complete aphonia, and this by coma and death. The introduction of ventilating appliances caused the disappearance of this singular disease, and in time these metal boxes, almost entirely submerged, came to be regarded as probably the most salubrious vessels afloat. The mechanical means of ven-

tilation now introduced were not, in spite of this object lesson, generally applied, for even as late as 1880 there was only one cruiser in the United States Navy in which this system was in use.

The monitor type, the scarcity of lumber in Great Britain, the increase in the size, power, and efficiency of ordnance necessitating greater strength, the economy and other manifest advantages of iron in shipbuilding, and the improvements in metal working were, however, together with other considerations and the plentifulness of iron, effecting a general change in naval architecture. In a short time it became evident that the days of wooden vessels were numbered, and then all maritime powers hastened to construct the present engines of war, —veritable steel forts, whose history is yet but partially made.

In comparing the navy of the present with that of the past it may be stated that, from a sanitary point of view, the most important changes are closely associated with the difference in material of construction. Steel rusts and wood decays. The one is purely chemical, while the other is vital. The one is a simple process of oxidation, hastened by moisture and probably by electrical disturbances, but, as a rule, entirely independent of vital influences; the other is usually a complicated change,—a variety of death,—in which complex molecules formed by plant life are broken down into simpler compounds through the influence of animal and vegetable parasitic growth. The one is comparable to a slow burning, the other to a putrefaction. A decayed ship is, therefore, much like a dead body, particularly in those parts most subject to bacterial and fungous growth. The difference between the present ship and that of the past, in this connection, is, therefore, very evident.

The physical properties of wood and steel also differ in the one being absorbent and full of cracks and crevices for the accumulation of filth and the other impervious and its pieces capable of a more complete coaptation. These considerations have a very evident and important bearing upon infection, air pollution, cleanliness, and disinfection. Steel is also lighter than wood, strength for strength. This favours increased tonnage, provides more space, and, in lessening the size of beams and knees, furnishes fewer obstructions to the circulation of air. Armour plating of sides and increased weight of ordnance have also caused greater beam and tonnage, and, with abolition of sail power, have diminished, relatively, the number of men and largely increased the cubic air space per head. But iron and steel have a much greater specific gravity than wood, or water even. While every part of a wooden ship would float, the opposite is true of iron. Consideration of safety at sea and in battle have led to the division of a ship by bulkheads into a number of water-tight compartments and to the construction of a double bottom. The latter extends across the bilge, and is, of course, absolutely water-tight when the manhole plates are on. The air between the bottoms is, therefore, entirely stagnant and the space dry, though drainage is provided into wells which could be emptied by powerful pumps.

The bilge of a modern man-of-war is, therefore, from a sanitary point of view, outside the vessel, as its air is confined, and it is shut off from the receipt of any refuse material whatever. Yet now that it has ceased to menace health, no portion of a ship receives greater care and attention, for the question is not one of sanitation, but of preservation of structure,—the life of the ship, and not that of the men. Manhole plates are lifted with regularity, air is renewed by portable ventilators, and men are especially employed to crawl through the space and take care of the metal bottom, which seeks to destroy itself by rusting. The old story of the bilge has, however, come to an end, and new conditions have arisen to confront the sanitarian. But with the growth of knowledge in all parts of the world, the advance in mechanical invention, the rapidly growing insight of medical and surgical minds into the cause of disease, and the more general diffusion of information on matters relating to health, there appears at

least a promise of the abolition of the surroundings necessary for the existence of many diseases long considered the curse of the human race.

The arrangement of guns in turrets and in other systems, occupying the former spar deck, occluding to a great degree its openings and abolishing the old gun ports, and the division of ships into compartments, created a number of confined spaces in which men have to sleep and work, have led, from necessity, to the introduction of mechanical means for the withdrawal of vitiated air between decks and the supply of pure air, which has surrounded all seagoing vessels from the beginning. The appliances for this purpose have been so improved that it is now possible by the use of the rotary fan to extract from, or force into, each compartment any desired quantity. The incoming air is, however, not warmed, and this, with the small amount of cubic space occupied by each person, limits the supply necessary for a proper renewal. The question of draughts thus assumes a place of the greatest importance in the problem, and its comparative solution becomes a question of great moment. Besides, the amount of air going into a space and the amount coming out are not a true indication of the general circulation. In this connection it is also apparent that the smaller the number of openings of entrance and exit, the more rapid will be the circulation in certain localities for any given supply and the less the diffusion. Room for improvement is, therefore, apparent in the direction of increase in apertures,—the maximum being the entrance and departure of air through openings as multitudinous as those in gratings everywhere distributed. The mechanical difficulties are, however, far from small, and considerations of cleanliness would also have to be successfully met. Even now the ventilation of certain spaces is much diminished by friction in pipes increased by bends. These and other recognised defects, often apparent, lead to the expression of opinion that each important compartment should have its own ventilating system of sufficient power, and that the greatest movement of air compatible with health should be secured by scientific experimentation made by persons having this duty assigned them. The subject has now come within the range of mathematical precision, but accuracy can be secured only by a regularly organised supervision and a sense of individual responsibility.

The question of moisture on vessels of war has now presented itself under new circumstances. The old contention of wet or dry decks seems to have been definitely and satisfactorily settled the world over. Knowledge on the subject has at last become the common property of nearly all naval commanders. Great care is now exercised in frequently covering all berth decks with shellac or other mixtures, and in securing cleanliness with the smallest amount of warm water. But the change from wood to iron and steel as materials of construction has caused new, but not unexpected, difficulties in this connection. Wood is a poor conductor and absorber of heat. Iron and steel heat and coo rapidly. A metal ship is, therefore, exceedingly warm in tropical summers and cold in the winters of high latitudes. The latter is, to a great extent, controlled by the plentiful use of steam confined in coils, but the skin of the vessel remains exceedingly cold, and, to any one sleeping near it, seems much like ice itself. The former is limited by the application exteriorily of white paint, as this colour promotes the reflection of the sun's rays. Both are much diminished by an inside sheathing. This has become common in officers' quarters where bunks are provided, but its continuance is problematical, inasmuch as recent experience in war has disclosed the danger of conflagration in battle.

The property possessed by metal of cooling rapidly reduces the power of air in contact with it to retain moisture. As a result, water is deposited in quantity depending upon the state of the atmosphere and the coldness of the surface to which it is exposed. The phenomena is known as "sweating," and the condition is one exceedingly detri-

mental to health. It is true that so long as the condensation continues uninterrupted the air is deprived of moisture, but as the ship is heated by the sun a rapid evapouration ensues and human exhalations that would have escaped are suddenly set free. Besides, the organic poison from the skin and breath are by this water carried to a certain extent over the ship, inasmuch as the different parts are arranged so as to drain into wells on the upper surface of the double bottom. Fortunately, the presence of water on iron facilitates rusting, and thus excites apprehension relating to its durability. It also in this manner tends to mar the clean surface of the paint work and to destroy the beauty of cleanliness. This has led to the use of paint containing a considerable quantity of cork, the wood acting as an excellent non-conductor. The difficulty, though not entirely met, has been considerably reduced, and promise is given that the future has much needed improvements still in store. This question, however, as has been indicated, is not one confined strictly to the physical properties of the material of construction. The relation existing between ventilation, the temperature of air between decks, and this tendency to the deposit of moisture, is one demanding more attention than it has ever received. Inasmuch as a vessel of war may be required for duty along the coasts of any country where human beings can live, efficiency will depend to a great extent upon the adaptability of structure to rapidly changing climatic conditions. The supply of heat in connection with ventilation, therefore, assumes a prominent place, especially as it depends upon this in a great measure whether a ship will be dry and wholesome or the reverse. It is, therefore, of vital importance that the distribution of heaters and area of heating surface should be considered in connection with ventilation, size of space, and probable or possible variations of temperature of outside air and water. Such attention this subject does not, to say the least, always receive, the desire being too often to free the decks as much as possible from steam heaters and to leave the supply rather to guesswork and supposed economy of space. It is, therefore, not unknown for a sick bay and berth deck to have for weeks an average temperature of 51.5° F., with a maximum of 60° and a minimum of 44°. As a result, heavy frost has appeared on the ship's sides and bulkheads, and at times it has been necessary to protect the sick in their cots and hammocks by rubber sheets spread overhead. The effects of such a condition upon health and the determination of disease needs no comment.

Much has been said and written in regard to the treatment of disease occurring at sea. It would appear, however, that the portion of the ship set apart for the sick has much to do with the result in a large number of cases. The traditions of hundreds of years have fastened the idea that a place at the bow must be devoted to this purpose, though it is the most unfit for the service to be performed. The shape of a vessel and the condition of being afloat render this the point of greatest motion, and, owing to the hawse holes, the one most liable to be flooded by the sea. It is the one place in which air ports must be kept rigorously closed at sea, and, barring the engine, it is the noisiest locality on shipboard, though even this exception cannot be made when the chain rushes through as the anchor goes down or follows the anchor engine in its rounds. The effect of the ship's motion on the sick has never probably been thoroughly investigated, but, doubtless, in pneumonia and other acute diseases it tends to paralyse a heart already much weakened. It certainly increases the difficulty in the management of a variety of injuries.

In conclusion, it may be stated that it has not been the intention to treat the subject of naval architecture and ship sanitation in any but a general way. Details have to be worked out from general principles with the aid of individual experiences. Valuable lessons may, however, be learned from the history of each subject of importance, and surely even an incomplete study of the

causes of the mortality of the sea will not prove an exception. Perhaps the one fact that stands above all others is that suffering, so closely associated with wounds on shipboard during action, and with disease and death, in spite of the irretrievable loss it entails, has influenced but little the minds of men who have built from the beginning the great navies of the world. Changes have occurred from considerations relating to the durability of ships and their perfection as engines of war. The mariner's compass, gunpowder, and steam have each marked an era in shipbuilding, and though the mortality of seamen has been greatly reduced, they each tell the same story of human life depending, so far as naval architecture is concerned, upon the preservation of wood, strength of structure, and conditions evolved during battle. Now the iron or steel age begins. Shall we learn any lesson from the past, or will future ages trace out the same indifference to the life of man? It is believed that such is not the tendency of the time.

The writer desires, in closing, to express his appreciation of the able assistance rendered him in the preparation of this paper by Passed Assistant Surgeon J. D. Gatewood, United States Navy, at the Museum of Hygiene, Washington, D. C.

THE INCREASING SIZE OF AMERICAN LOCOMOTIVES

A LOOK INTO THE FUTURE

By William Forsyth

IN measuring the progress of affairs in the industrial world, a comparison of modern achievements with those of a previous age will, of course, show a greater contrast the further back the investigation is extended. For the present purpose the writer will not deal with the early development of the locomotive in the United States, but will commence when locomotive design had settled down to rather well-defined lines which bear some resemblance to those in use at the present day.

The dividing line between the present and the early transitional period in locomotive practice may be taken at the time the Stephenson link motion was regularly introduced,—1855 to 1860. We may take for our comparison the type of passenger locomotive known as the American 8-wheel engine, having four driving wheels and a 4-wheel truck. A good illustration of the passenger engine of the early period is shown in Fig. 1. This was built from designs made by Mr. George Cushing, by the Chicago & Northwestern Railway in 1867. The cylinders were 16 × 22 inches and the wheels 60 inches; the boiler shell measured 46 inches, fire-box 39 × 54 inches, and the total weight was 61,000 pounds. Passenger engines at that time were ornamented with scroll work, polished brass and bright colours. The illustration shows the extent to which scroll decoration was then used.

In 1870 passenger engines began to assume a more severe and business-like appearance, with plainer finish. As typical of this period a passenger engine is shown in Fig. 2, built by the Baldwin Locomotive Works. The cylinders are 16 × 24 inches, and wheels 60 inches; the boiler shell is 48 inches, grate 66 × 34½ inches, weight on drivers 41,000 pounds, and total weight 65,000 pounds.

Fig. 3 shows the passenger engine used on the Pennsylvania Railroad in 1873, and the growth of this type of locomotive can be best illustrated by showing cuts of the Pennsylvania Railroad passenger engines in subsequent years. In 1881 the Class K engine (Fig. 4) was designed and built. This attracted attention on account of the large size of the driving wheels, which measured 78 inches. The cylinders were 18 × 24 inches, the boiler pressure was 140 pounds, diameter of boiler shell 50 inches, weight on drivers 64,000 pounds. In 1890 the Class O engine was built, with cylinders 18 × 24 inches, boiler pressure 160 pounds, boiler shell 57 inches, grate area 17.6 square feet, heating surface 1283 square feet, driving wheels 68 inches, weight on drivers 61,450 pounds.

The Class P engine, as built in 1890, is shown in Fig. 5, with principal dimensions similar to Class O, but with cylinders 18½ × 24 inches, and weight on drivers increased to 73,350 pounds. In 1895 the Class P engine was redesigned and enlarged, and it then presented the appearance shown in Fig. 6, the cylinders measuring 19 × 24 inches. The boiler pressure was 175 pounds, the driving wheels were 80 inches, and

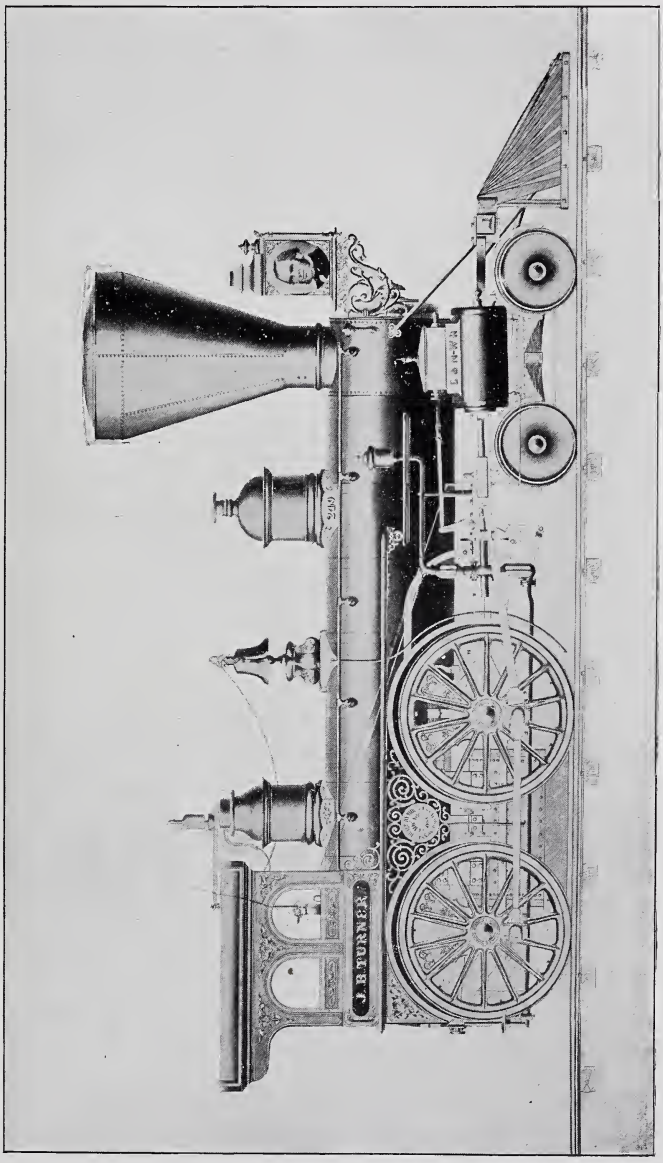


FIG. 1.—AN EARLY PASSENGER LOCOMOTIVE BUILT BY THE CHICAGO & NORTH WESTERN RAILWAY CO., AT CHICAGO, IN 1867, AFTER THE DESIGN OF GEORGE W. CUSHING, MASTER MECHANIC

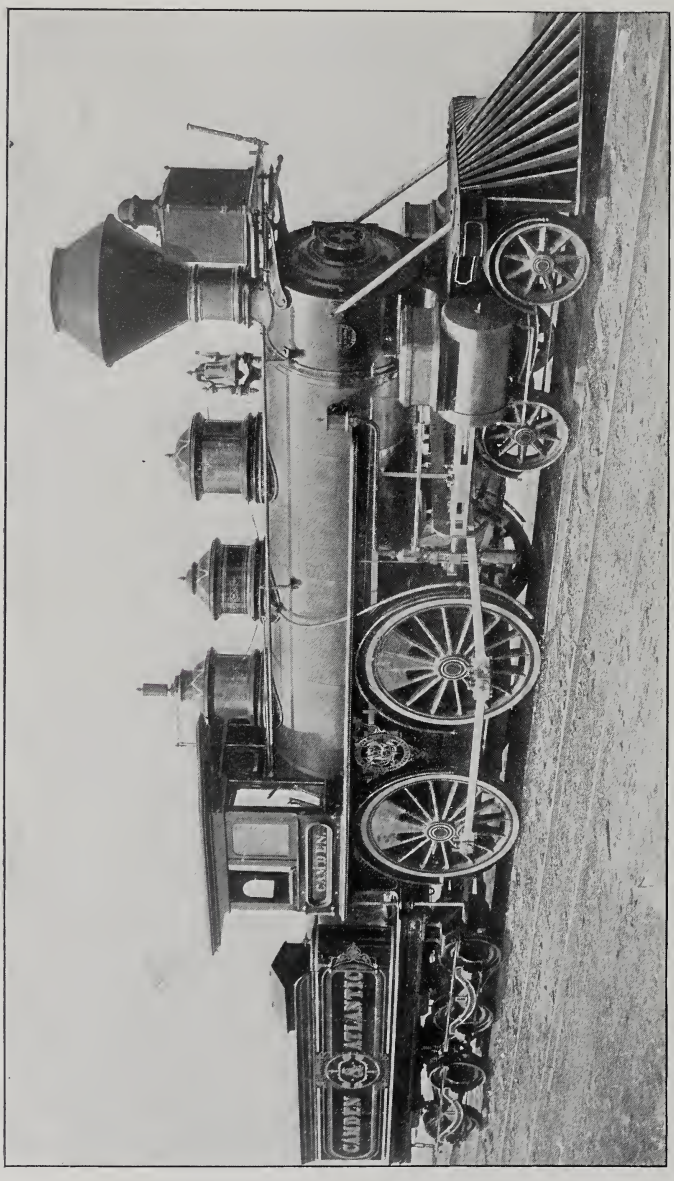


FIG. 2.—A STANDARD AMERICAN PASSENGER LOCOMOTIVE OF 1870. BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

the weight on the drivers was 87,300 pounds.

The Class L engine (Fig. 7), built in 1896, is a still further enlargement of the Class P, with cylinders 18½ × 26 inches, boiler pressure 185 pounds, driving wheels 80 inches, boiler shell 60 inches, grate area 33 square feet, total heating surface 1900 square feet, weight on drivers 91,600 pounds. A good idea of the growth in size of the complete locomotive is gained by a comparison of the Pennsylvania Railroad passenger engine Class G, constructed in 1873 (Fig. 3), and that of Class L, built in 1896 (Fig. 7), the cuts being

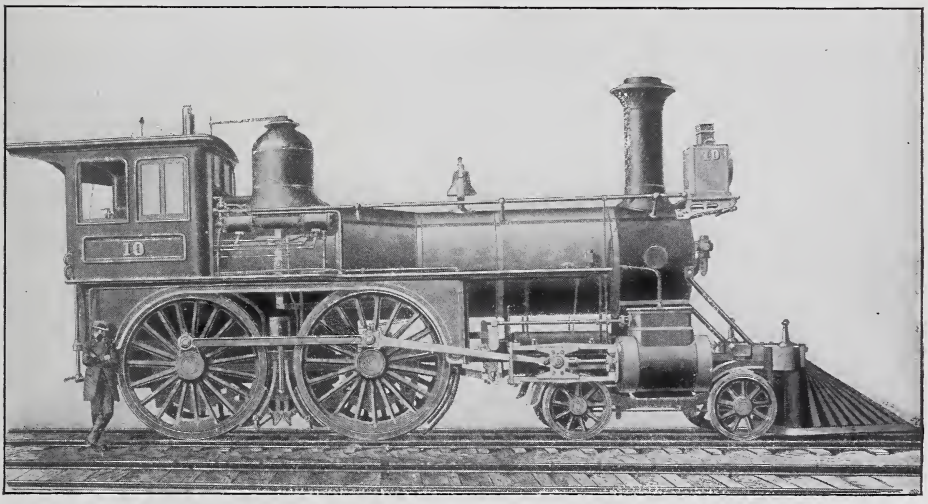


FIG. 4.—FAST PASSENGER LOCOMOTIVE OF THE PENNSYLVANIA RAILROAD COMPANY. BUILT IN 1881 AT THE ALTOONA, PA., SHOPS OF THE COMPANY

from a photograph of the two engines coupled together.

The class L engine represents the highest development of the American 8-wheel passenger engine, both in design and size. The heavy engines of this type built for the Chicago & Northwestern Railroad by the Schenectady Locomotive Works, of Schenectady, New York (see Fig. 19), have larger boilers, the diameter of shell being 64 inches, and the total heating surface 2507 square feet, while the cylinders are 19½ × 26.

Engines of this type recently built for the Chicago & Alton Railroad by the Brooks Locomotive Works, of Dunkirk, New York, are nearly as large as either of the above, and exceed them in having a total weight of 139,000 pounds. Ten years ago it was said that the 8-wheel passenger engine had reached its maximum growth, but it has continued to increase in size until it has reached the gigantic proportions given above.

Whenever the requirements have imposed too great a wheel weight for poor track, resort has been had to the Mogul, or 10-wheel type, having six driving wheels. A recent example of a very large 10-wheel passenger engine is that shown in Fig. 8, built for the Lake Shore road by the Brooks Locomotive Works. The cylinders are 20×28 inches, the drivers 80 inches, and the boiler shell measures 66 inches; total heating surface 2917 square feet, grate area 34 square feet, weight on drivers 133,000 pounds, and total weight 171,600 pounds.

The latest passenger engine designed for the Pennsylvania Railroad is the Atlantic type, shown in Fig. 9. In this the driving wheels are placed under the barrel of the boiler, and the fire-box, being clear of the drivers, can be made of any desired width. Being supported by trailing wheels of small diameter, it

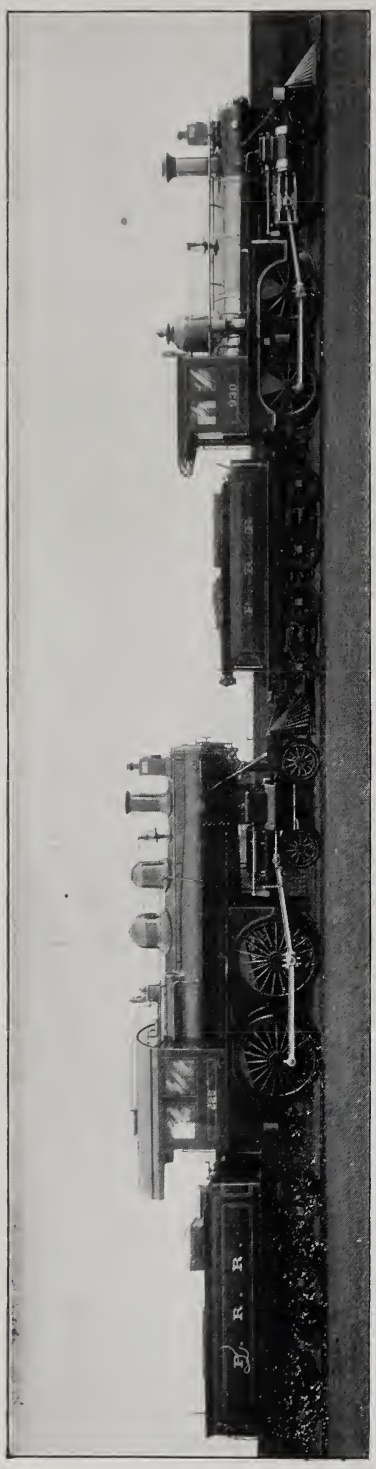


FIG. 7.—STANDARD LOCOMOTIVE IN 1896

FIG. 3.—STANDARD LOCOMOTIVE IN 1873

TWENTY-THREE YEARS' PROGRESS IN PASSENGER ENGINE CONSTRUCTION ON THE PENNSYLVANIA RAILROAD

can be kept lower down, and for a proper depth of fire-box it is not necessary to elevate the barrel of the boiler as high as is required by the 8-wheel or 10-wheel type for equal boiler capacity. The Atlantic type, therefore, admits of further growth of passenger engines having only four drivers. The two prime requisites for high speed are large boiler capacity and large driving wheels, and the maximum limits of these elements can be carried further in the Atlantic type before a dangerous height of centre of gravity is reached.

Locomotive builders are rather timid about exceeding a height of 9 feet from top of rail to centre of boiler, and some builders make it a rule that the angle made by lines from the centre of the boiler to the rails should not exceed 30 degrees. In the case of the larger 10-wheel engine referred to, the height of the centre of the boiler above the rails is 9 feet 2 inches. The fastest schedules now worked in the United States are with engines of the Atlantic type, having wide fire-boxes, and driving wheels 84 inches in diameter.

It is probable that the future growth of the American passenger engine will be along the lines of the Atlantic type. As it has advantages not possessed by either 8-wheel or 10-wheel engines, few attempts will be made to further enlarge the 8-wheel engine, and the Atlantic type will be made larger and heavier as long as track conditions admit of heavier weights on four driving wheels.

In July, 1866, the first freight engine of the "Consolidation" type was built by the Baldwin Works for the Lehigh Valley Railroad from designs of the master mechanic of that road, Mr. Alexander Mitchell. It had eight driving wheels and a 2-wheel, or pony, truck. The cylinders measured 20 × 24 inches, and the drivers 48 inches. The weight on the drivers was 80,000 pounds, and the total weight of the engine was 90,000 pounds. This engine, shown in Fig. 10, may be regarded as the prototype of the modern freight locomotive, and in order to make conditions uni-

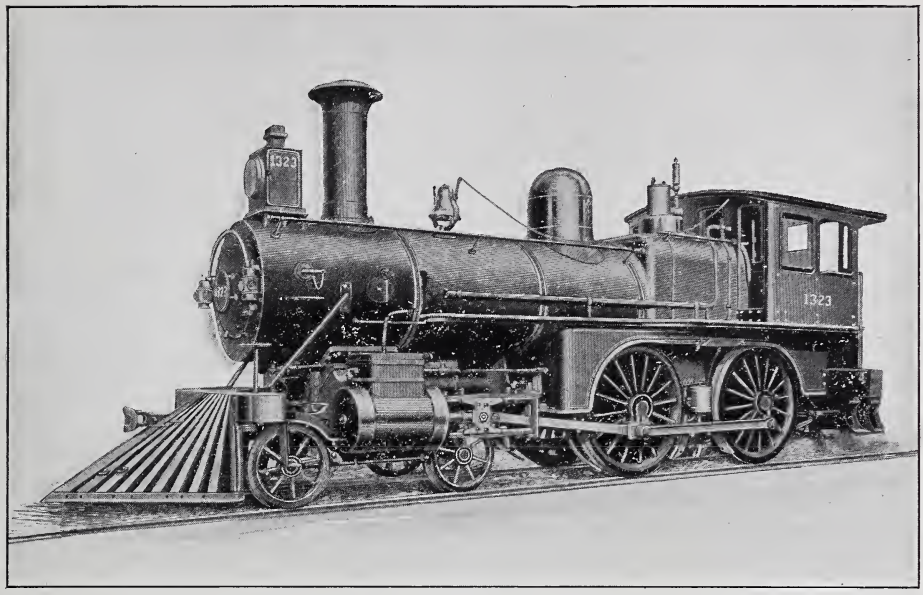


FIG. 5.—A PENNSYLVANIA RAILROAD ENGINE OF 1890

form the writer will confine his comparisons to this type.

During the twenty-five years after the original Consolidation engine was built but little change was made in the design and comparatively slight increase was made in the size and weight of this type. At the Centennial Exposition in 1876, ten years after, the Baldwin Locomotive Works exhibited another Consolidation engine, built for the Lehigh Valley Railroad, shown in Fig. 11. The cylinders are 20 × 24 inches, wheels 50 inches, the boiler pressure was 130 pounds, grate surface 27.6 square feet, total heating surface 1281 square feet, weight on drivers 88,000 pounds, total weight of engine 100,000 pounds.

In Fig. 12 is shown a Consolidation engine built by the Baldwin Works in 1881, and it will be noticed that it differs but slightly from those built in 1876. The principal dimensions were, cylinders 20 × 24 inches, wheels 52 inches, boiler shell 52 inches, grate 27.5 square feet, total heating surface 1165 square feet. The boiler pressure was 145 pounds, weight on drivers 88,000 pounds, and the total weight 102,000 pounds.

At the World's Fair at Chicago in 1893 the Baldwin Works exhibited the Consolidation engine shown in Fig 13. In this engine considerable growth, and size, and weight can be noticed. While the cylinders remained equivalent to 20 × 24 inches, the boiler pressure was increased to 180 pounds, the driving wheels were made 56 inches, and the boiler shell was 59 inches. The total heating surface was 1878 square feet, weight on drivers 120,600 pounds, and total weight 135,800 pounds.

In 1895 we find Consolidation engines with cylinders as large as 22 × 28 inches, and with weight on drivers of 148,000 pounds. In 1898 the Pittsburgh Locomotive Works built for the Union Railroad at Pittsburgh the largest Consolidation engine constructed up to that time. It is shown in Fig. 14. The cylinders are 23 × 32 inches, and the wheels are 54 inches in diameter. The boiler shell is 80 inches in diameter, grate area 33.5 square feet, heating surface 3322 square feet, boiler pressure 200 pounds, weight on drivers 208,000 pounds, total weight 230,000 pounds. Large as this engine is, it has since been exceeded in some dimensions by the

FIG. 6.—A PENNSYLVANIA RAILROAD DESIGN OF 1895

PRINCIPAL DIMENSIONS OF AMERICAN EIGHT-WHEEL PASSENGER LOCOMOTIVES, 1860 TO 1900.

	1860.	1870.	1880.	1890.	1895.	1900.	Atlantic Type, Wide Fire-Box. 1900.	Ten-Wheel Passenger, Lake Shore. 1900.
Cylinders	16x22 ins.	16x24	17x24	18x24	20x24	20x26	20½x26	20x28
Cylinder Volume (one)	2.55 cu. ft.	2.78	3.17	3.53	4.37	4.73	4.96	5.10
Driving Wheels, Diameter	60 ins.	66	68	72	78	78	80	80
Boiler Pressure	100 lbs.	120	125	160	180	210	185	210
Tractive Power	7,980 lbs.	9,040	10,800	14,500	19,000	25,000	21,000	25,000
Diameter Boiler Shell	46 ins.	48	52	54	60	66	66	66
Grate Area	15 sq. ft.	16	17	24	30	32	69	34
Total Heating Surface	900 sq. ft.	1,000	1,200	1,500	2,200	2,500	2,320	2,917
Weight on Drivers	38,000 lbs.	41,000	54,000	66,000	80,000	90,000	102,000	133,000
Total Weight Engine	61,000 lbs.	65,000	80,000	102,000	120,000	139,000	173,500	171,600

FREIGHT LOCOMOTIVES.

	Mogul.	Consolidation					Twelve Wheels	
Cylinders	18x22 ins.	20x24	20x24	20x24	22x28	23x32	23x30	------
Cylinder Volume (one)	3.23 cu. ft.	4.37	4.37	4.37	6.16	7.68	7.20	------
Driving Wheels, Diameter	54 ins.	50	52	52	52	54	57	------
Boiler Pressure	100 lbs.	120	125	160	180	210	210	------
Tractive Power	11,500 lbs.	19,500	19,500	25,000	40,000	56,000	------	------
Diameter Boiler Shell	48 ins.	50	56	60	72	80	82	------
Grate Area	20 sq. ft.	24	28	30	35	33.5	37	------
Total Heating Surface	950 sq. ft.	1,100	1,280	1,500	2,300	3,322	3,500	------
Weight on Drivers	62,000 lbs.	80,000	88,000	112,000	148,000	208,000	193,200	------
Total Weight Engine	70,000 lbs.	90,000	100,000	128,000	160,000	230,000	232,200	------

12-wheel engine built in 1899 by the Brooks Locomotive Works for the Illinois Central Railway. This engine is shown in Fig. 15. The principal dimensions are: — Cylinders 23 × 30 inches, driving wheels 57 inches, boiler shell 82 inches, grate area 37.5, heating surface 3500 square feet. The boiler pressure is 210 pounds, weight on drivers 193,200 pounds, total weight of engine 232,000 pounds. At the present time this is claimed to be the heaviest locomotive ever built.

The Lake Shore 10-wheel passenger engine shown in Fig. 8 is, doubtless,

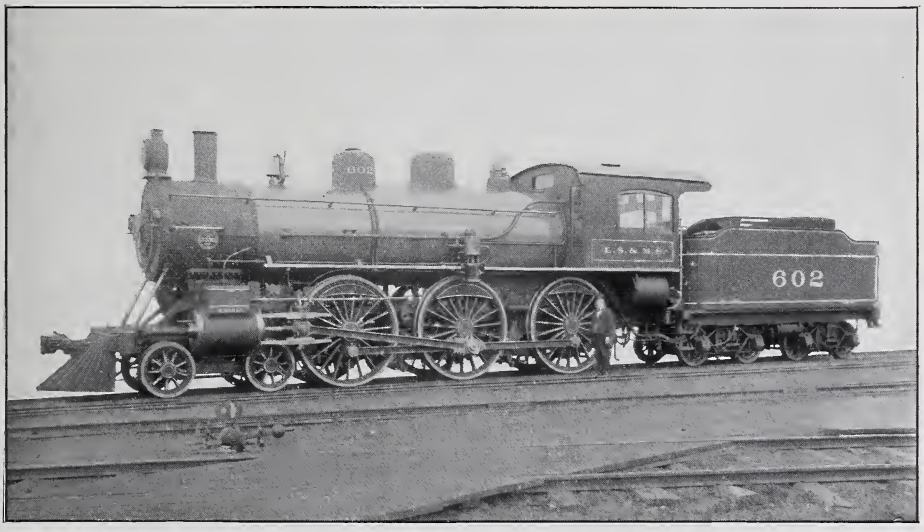


FIG. 8.—THE HEAVIEST EXISTING AMERICAN PASSENGER LOCOMOTIVE. TOTAL WEIGHT, 171,600 LBS.; WEIGHT ON DRIVERS, 133,000 LBS. BUILT BY THE BROOKS LOCOMOTIVE WORKS, DUNKIRK, NEW YORK

the heaviest passenger engine ever built, and with these two engines of maximum size and weight the writer would conclude the descriptive part of this article.

The dimensions which have been given are the principal ones which determine the capacity of the locomotive, and most of them have been used in the table opposite, in which the figures fairly represent the prevailing practice at intervals of ten years from 1860 to 1900 and including 1895.

It will be seen that in this period of forty years the American 8-wheel passenger engine has grown as follows: — Cylinders from 16 × 22 inches to 20 × 26 inches; comparative volumes (one cylinder) 2.55 cubic feet to 4.73 cubic feet. The cylinder on the Lake Shore 10-wheel passenger is 20 × 28 inches, and its volume 5.10 cubic feet, or just about double the capacity of that used in 1860. The diameter of the driving wheel has increased from 60 to 80 inches, some engines having 84-inch wheels, and the New York Central Railroad Company's famous engine No. 999 at the Chicago Fair had 86-inch drivers; but very few, if any, passenger engines have since been built with drivers as large as 86 inches. The boiler pressure has increased from 100 pounds to 210 pounds, and it is probable that locomotives may be built this year which will carry 250 pounds boiler pressure.

The tractive power has increased from 7980 pounds to 25,000, being now more than three times what it was in 1860. The diameter of the boiler shell has grown from 46 inches to 66 inches, the grate area from 15 square feet to 34 square feet, and, in the case of Wootten boilers, to 69 square feet. The total heating surface has increased from 900 to 2500 square feet, and to 2917 square

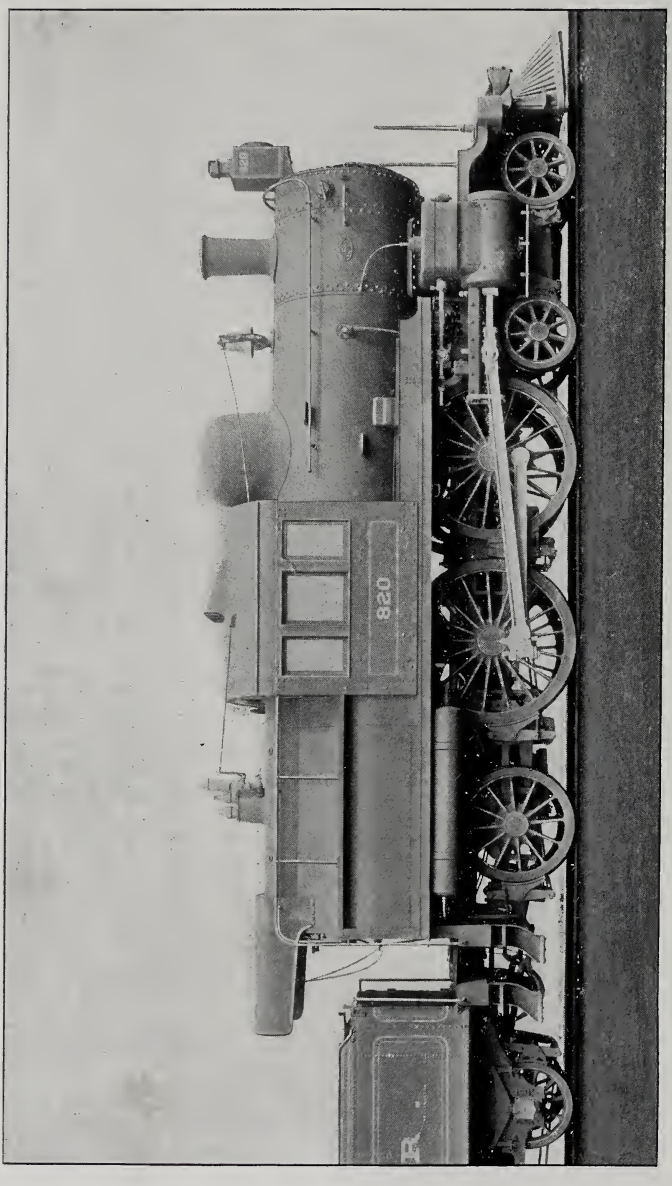


FIG. 9.—THE LATEST FORM OF PASSENGER ENGINE OF THE PENNSYLVANIA RAILROAD

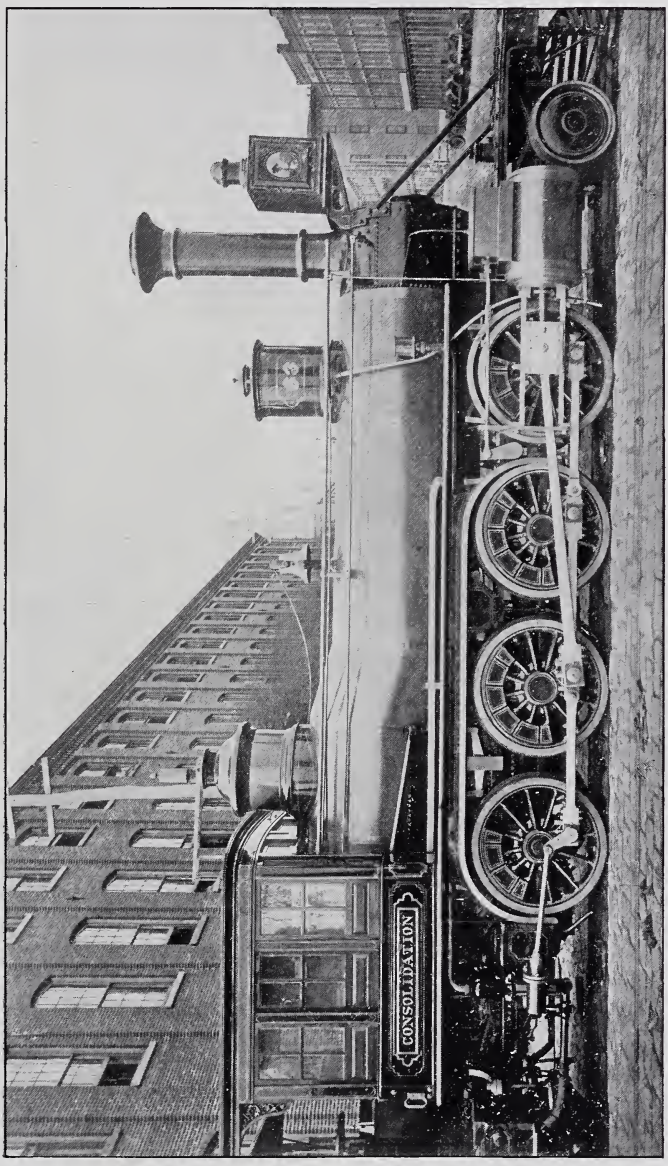
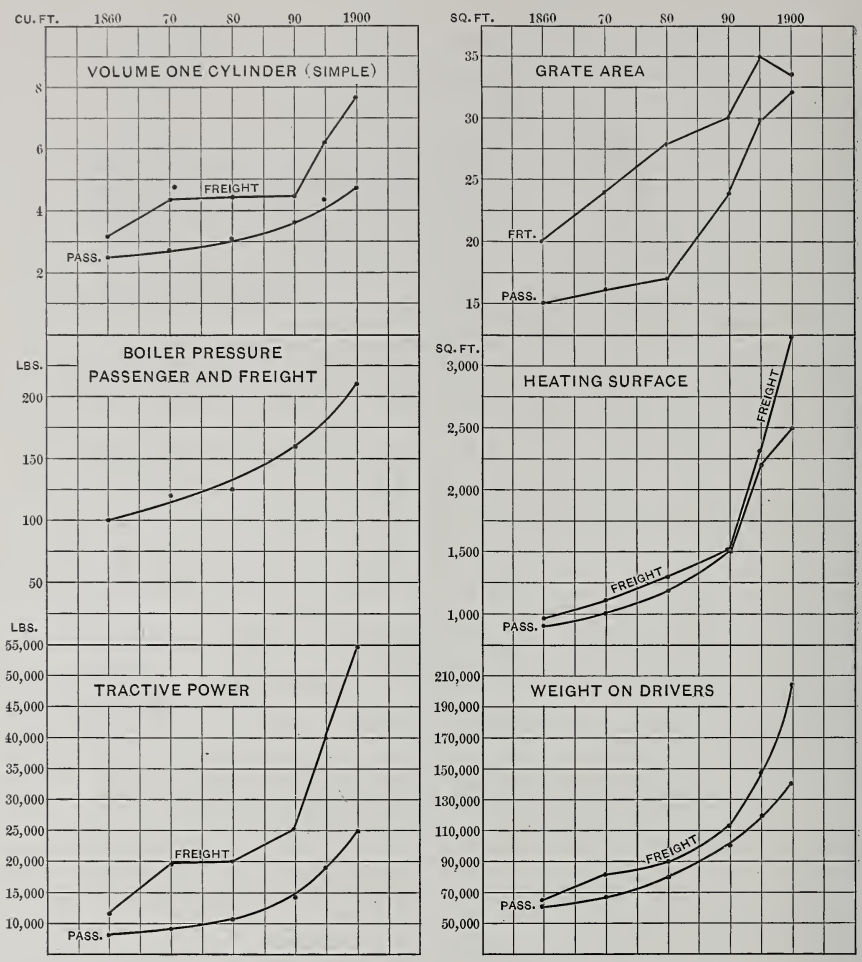


FIG. 10.—THE FIRST AMERICAN FREIGHT ENGINE OF THE "CONSOLIDATION" TYPE. BUILT IN 1866 FOR THE LEHIGH VALLEY RAILROAD BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA



GROWTH IN LOCOMOTIVE SIZES FROM 1860 TO 1900

feet in the large 10-wheel engine. The weight on drivers has grown from 38,000 pounds to 90,000 pounds, and the total weight of engine from 61,000 pounds to 139,000 for the 8-wheel type, to 171,600 for the 10-wheel, and to 173,800 lbs. for the Atlantic type.

In making similar comparisons with the figures for the Consolidation freight engine, the early period will commence about 1866 to 1870, and the later figures are for 1898. The cylinder has been enlarged from 20 × 24 to 23 × 32 inches, the comparative volumes being 4.37 cubic feet and 7.68 cubic feet. The table on page 152 shows but little change in diameter of drivers,—from 50 to 54 inches,—but the tendency is to use larger drivers, and recent Consolidation engines for the Lake Shore road have 62-inch drivers. The tractive power has increased from 19,500 to 56,000 pounds, being now nearly three times that obtained in 1866.

The diameter of boiler shell has grown from 50 inches to 80 inches, the grate area from 24 square feet to 35 square feet, and total heating surface from 1100 square feet to 3322 square feet. The weight on drivers has increased from 80,000 pounds to 208,000 pounds, and the total weight of engine from 90,000 pounds to 230,000 pounds. The maximum weight is reached by the Illinois

Central 12-wheel engine, with a total weight of 232,200 pounds.

In order to show whether the growth of the locomotive has been uniform or erratic, some of the figures in that table have been plotted in the diagrams on the opposite page. From these we see that the cylinder volume of passenger engines has increased steadily, but more rapidly since 1890 than previous to that time. For freight engines the cylinder volume was stationary from 1870 to 1890, but it has increased steadily and very rapidly since that time. The boiler pressure for both passenger and freight engines has increased steadily, the increase being greater for each succeeding decade.

The tractive power of passenger engines increased very little from 1860 to 1880, but since that time the growth has been rapid, and since 1890 greater than for the ten years previous. The grate area of passenger engines increased very slightly from 1860 to 1880, more rapidly from 1880 to 1890, and still faster from 1890 to 1895. Since 1895 the increase has been but slight. For freight engines the area of grate increased slowly, but regularly, from 1860 to 1895, and more rapidly from 1890 to 1895; and for fire-boxes flush with the outside of frames the size attained in 1895 has not since been exceeded; in fact, later engines of large size have somewhat less grate surface.

For both passenger and freight engines the grate area has not been increased in proportion to the cylinder volume, and it is a natural consequence that the coal economy obtained from smaller locomotives has not been maintained in the larger ones. In order to get a proper grate area for large modern locomotives it will be necessary to extend the fire-box beyond the frames so that the grate surface in square feet will be about four times the volume of both cylinders in cubic feet.

Referring again to the diagrams, we notice that the total heating surface of boilers of both passenger and freight locomotives, like the grate area, increased slowly from 1860 to 1890, and since that time has grown very rapidly. The advantage of a larger ratio of heating surface to grate surface, and a larger

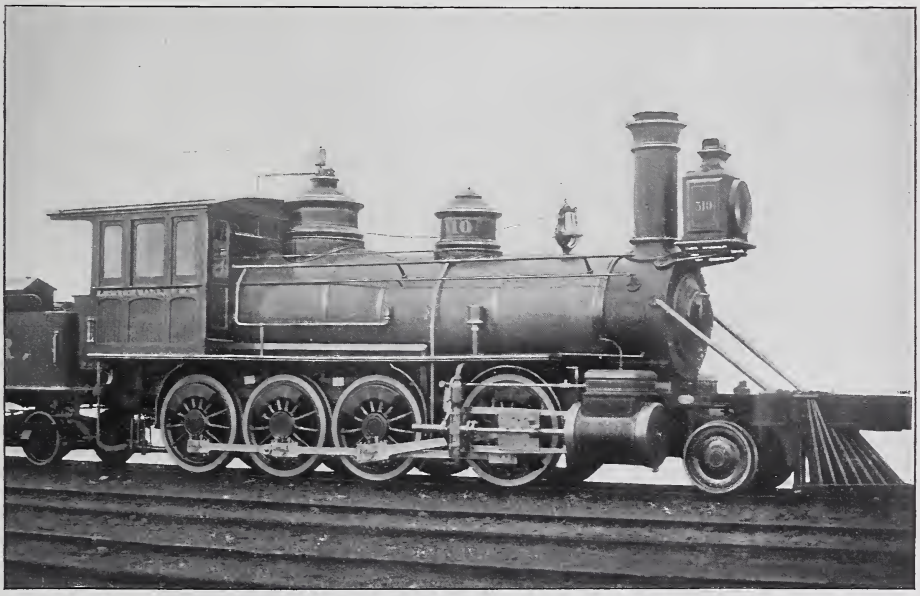


FIG. 11.—CONSOLIDATION ENGINE EXHIBITED BY THE BALDWIN LOCOMOTIVE WORKS AT THE PHILADELPHIA CENTENNIAL EXHIBITION IN 1876

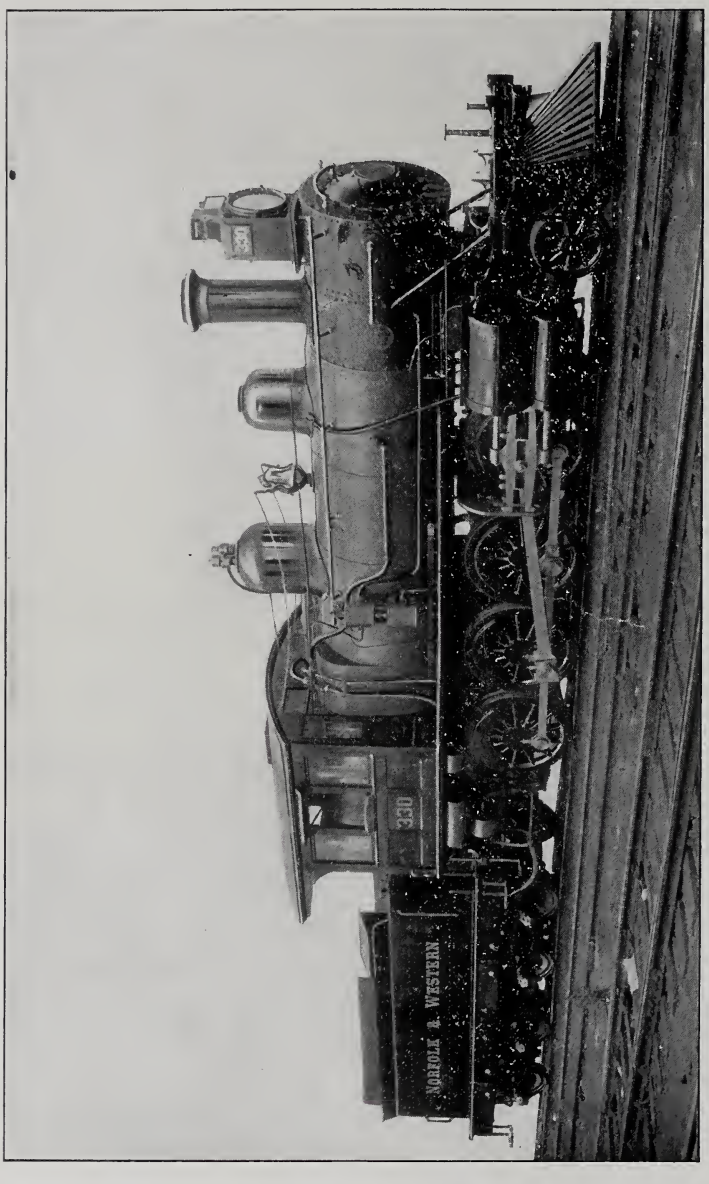


FIG. 13.—CONSOLIDATION ENGINE SHOWN AT THE WORLD'S FAIR AT CHICAGO IN 1893, BY THE BALDWIN LOCOMOTIVE WORKS

one than prevailed previous to 1890 has been frequently demonstrated, and is now so well appreciated that larger boilers are always used in modern locomotives, and the tendency is to push the size of boiler to the utmost limits allowable. The weight on the drivers has grown at nearly the same rate for passenger and freight engines up to 1890. Since that time freight engines have been built so large and with more drivers that the weight on drivers has increased faster than for passenger engines. From 1895 to 1900 this increase is still more marked. The lines in these diagrams all show a moderate growth in all dimensions up to 1890, and from that time to the present the growth has been very rapid, especially since 1895.

The slow growth of the locomotive during the thirty years up to 1890 was caused principally by the use of light rails and poor track generally, and to the limitations which civil engineers and roadmasters placed on maximum driving wheel weights. Iron rails were generally used up to 1876 and the section was small. Even after the track was well ballasted and made capable of sustaining heavy loads, it was supposed that if the load exceeded 14,000 pounds per wheel the surface of the rail would be rapidly and irregularly worn, because the pressure per square inch of wheel-bearing would then exceed the elastic limit of the steel.

In 1881 a prominent civil engineer made some experiments to ascertain the intensity of pressure per square inch produced by driving wheels on rails, and his results showed that a driving wheel five feet in diameter, with 14,000 pounds load on it, produced a pressure per square inch on the rail of from 50,000 to 80,000 pounds, which exceeds the elastic limit of rail steel. This idea that the rails would be crushed on the top surface if locomotives were built with weights exceeding 14,000 pounds per wheel prevailed for a long time, and imposed limits which prevented the more rapid growth of the locomotive. While some crushing and wear, doubtless, does take place under such conditions, it is found possible to greatly exceed the old limitations without serious consequences.

The competition between different

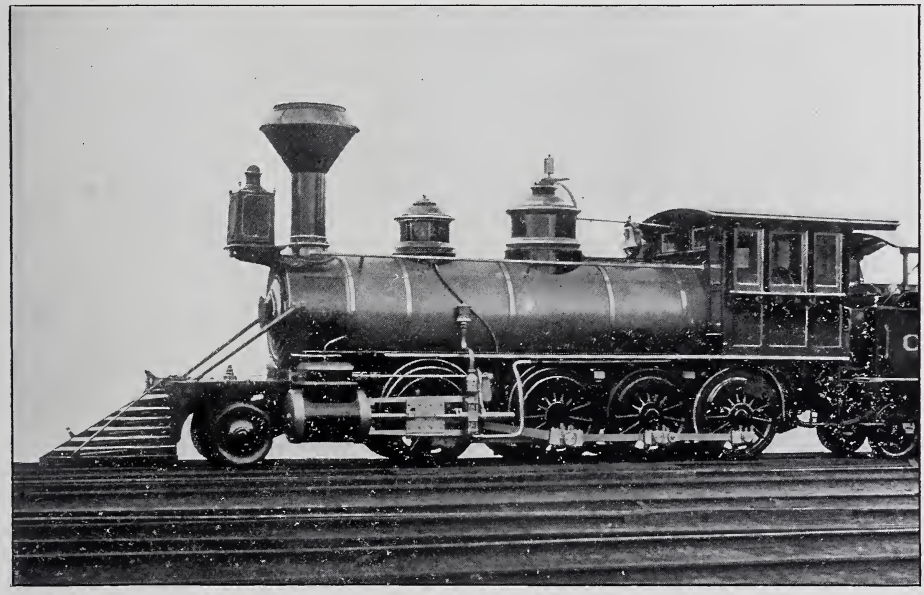


FIG. 12.—A CONSOLIDATION LOCOMOTIVE BUILT BY THE BALDWIN LOCOMOTIVE WORKS IN 1881

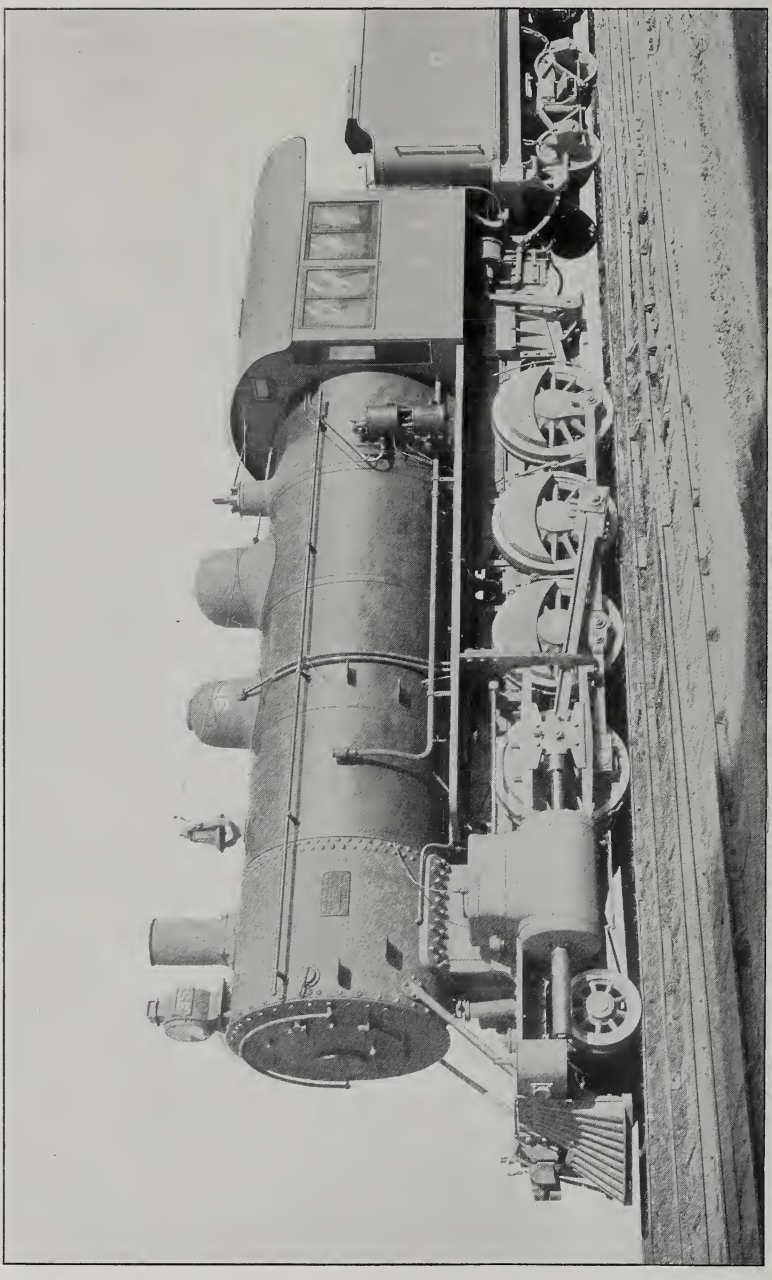


FIG. 14.—A CONSOLIDATION ENGINE BUILT BY THE PITTSBURGH LOCOMOTIVE WORKS, PITTSBURGH. TOTAL WEIGHT, 230,000 LBS.; WEIGHT ON DRIVERS, 208,000 LBS.

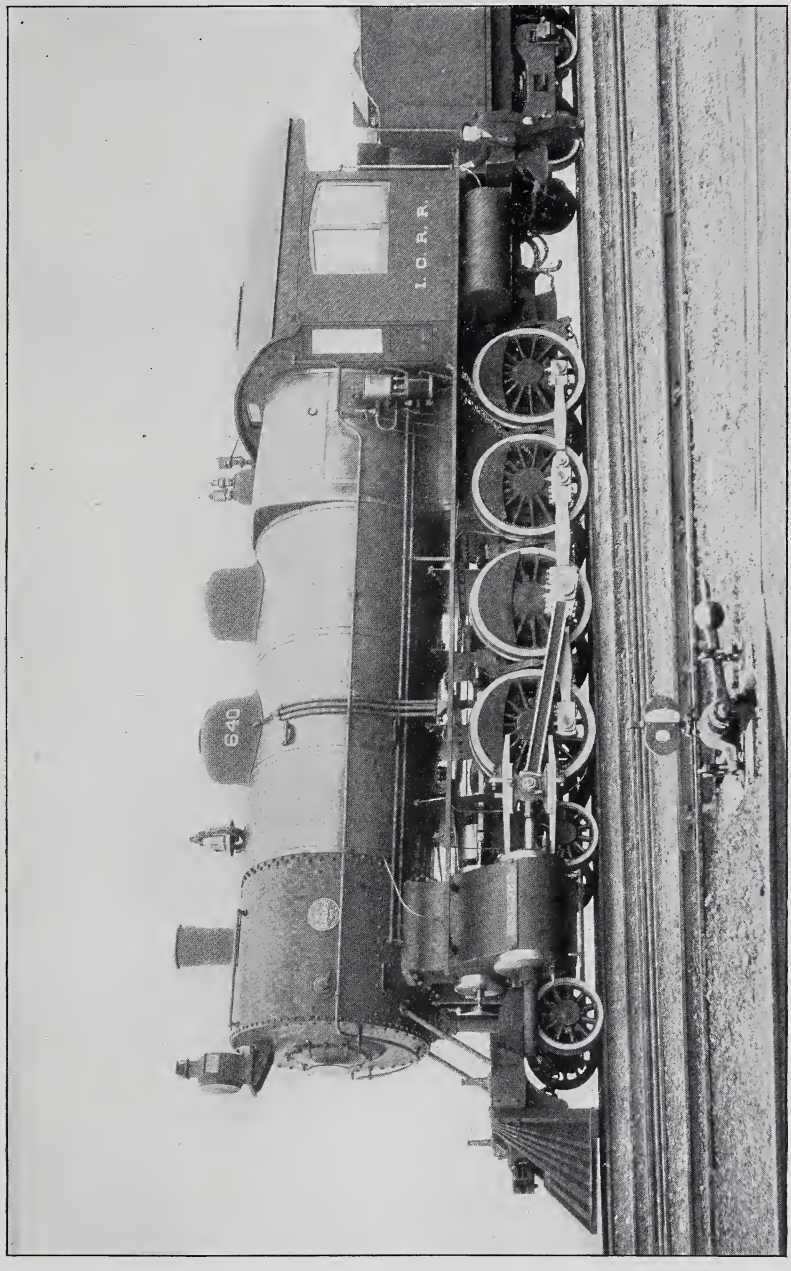


FIG. 15.—THE HEAVIEST LOCOMOTIVE IN THE WORLD. TOTAL WEIGHT, 232,200 LBS.; WEIGHT ON DRIVERS, 193,200 LBS. BUILT FOR THE ILLINOIS CENTRAL RAILWAY BY THE BROOKS LOCOMOTIVE WORKS, DUNKIRK, N. Y.

FIGS. 16 AND 17.—STANDARD TYPES OF LOCOMOTIVES BUILT BY THE COOKE LOCOMOTIVE & MACHINE CO., PATERSON, NEW JERSEY

railroads in the speed of passenger trains soon made a larger boiler necessary to supply the steam demanded by such service, and with larger boilers, cylinders, and wheels the weights of passenger engines increased until now we have the 8-wheel type with over 90,000 pounds on four drivers, or 22,500 pounds per wheel, and the Atlantic type with more than 100,000 pounds on four drivers, or 25,000 pounds per wheel. The dull period from 1893 to 1896 developed numerous economical methods of operation on railroads, and perhaps one of the most important was the rating of the hauling capacity of locomotives and the size of freight trains on a basis of tonnage instead of number of miles run and number of cars hauled, as had been the previous practice. This system of

working soon showed the advantage of larger freight engines, and since 1896 there has been a wonderful increase in the size of this class of power. An example has been given in the preceding pages of the Consolidation type with 208,000 pounds on eight driving wheels, or 26,000 pounds per wheel. This is about double the wheel weight which was thought a proper maximum limit in 1880. It is true that since that time the rail section has increased from 56 pounds to 90 and 100 pounds per yard, and the hardness of the steel is somewhat increased; but there is not much doubt that such heavy power is operated at the expense of rapid rail wear. With cheap steel rails, however, the heavy engines are found economical in special service in spite of rapid rail wear.

To any one reading what has already been said on the growth of locomotives in the United States, the natural question will occur, How long can this rapid growth continue, and what are the maximum limits of the size of passenger and freight engines? Carefully conducted tests of the economy and efficiency of high-speed passenger engines, and the very heavy freight engines have not been made during this later period of rapid development, and the exact effect of heavy wheel weights and high speeds on hard steel rails of large section is not known, so that it is difficult for railroad men to decide whether or not much further enlargement of the locomotive is desirable. Perhaps it is not wise to make any prophecy as to how the steam locomotive will have developed by the year 1905, and it is certainly best not to go beyond that year, for, if the present rate of growth be maintained, it must soon result in some radical changes in design which cannot now be imagined.

We may, however, make a natural extension of the lines of the diagrams and consider briefly the maximum limits to which they will lead us in the year 1905. The freight engine only will be taken, as this class is already the largest, except in the diameter of driving wheels. The cylinder volume of simple freight engines would be 10 cubic feet and require a cylinder equal to 28 inches in diameter and 30 inches stroke. The boiler pressure would reach 250 pounds, which is not unlikely, and it is probable

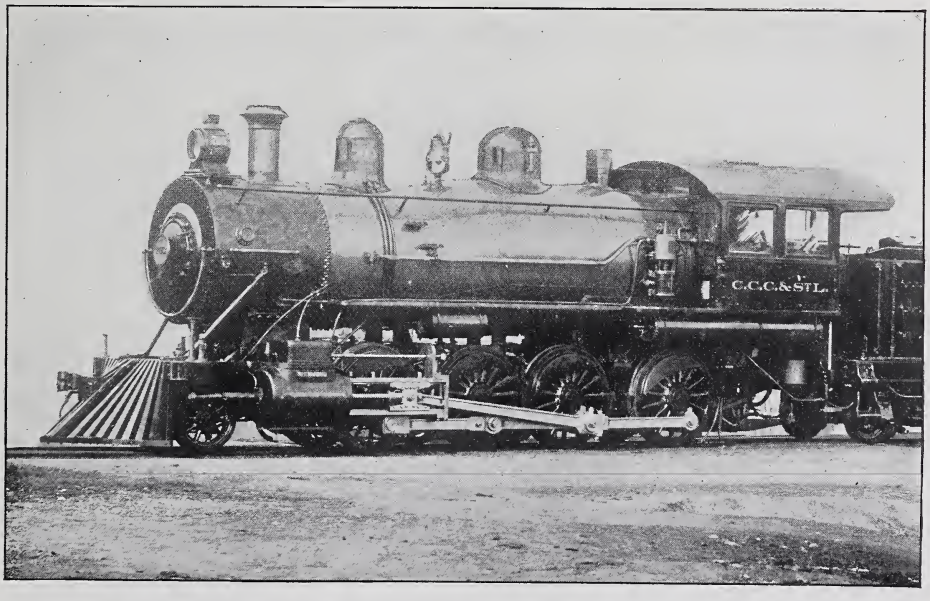


FIG. 18.—A CONSOLIDATION ENGINE BUILT BY THE RICHMOND LOCOMOTIVE AND MACHINE WORKS, RICHMOND, VA.

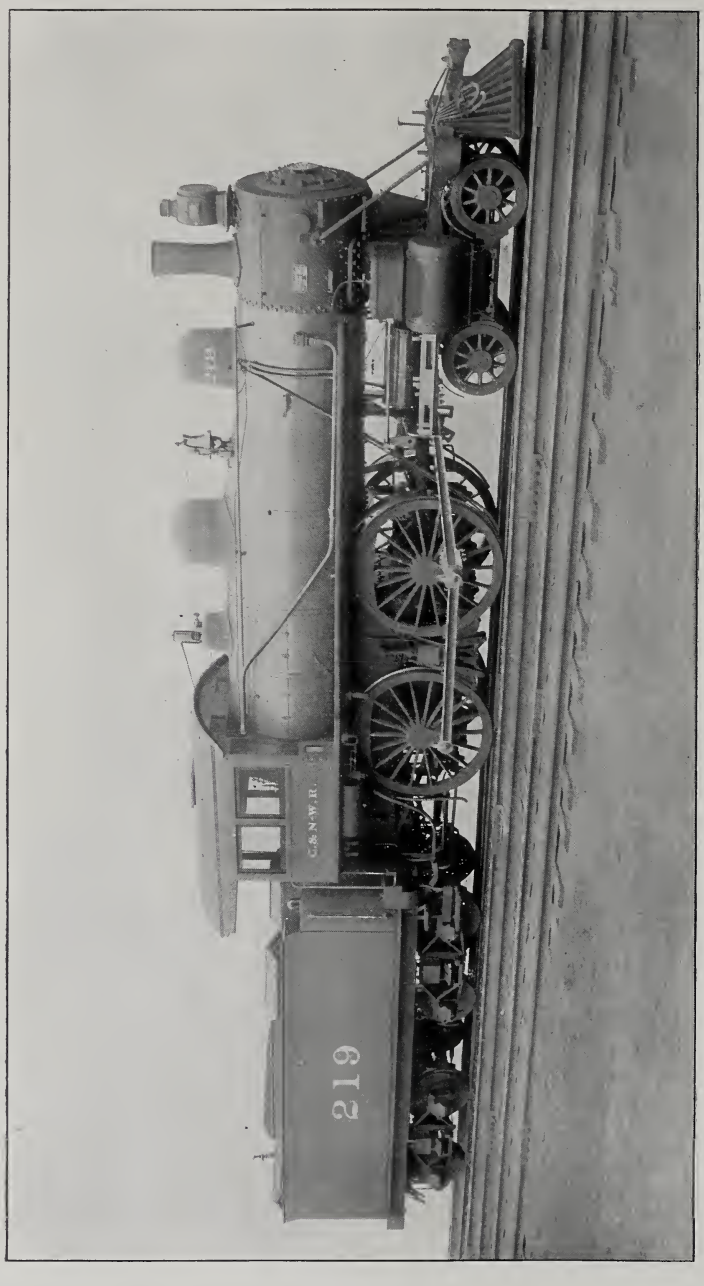


FIG. 19.—A HEAVY PASSENGER LOCOMOTIVE BUILT FOR THE CHICAGO & NORTH WESTERN RAILWAY BY THE SCHENECTADY LOCOMOTIVE WORKS, SCHENECTADY, NEW YORK

that in the next five years it will be increased to 300 pounds.

The grate area also will, doubtless, increase more rapidly in the next five years than it has since 1895. The practice is growing of extending the fire-box beyond the frame a moderate distance as a compromise between the very wide Wootten boxes, 8 feet wide, and the narrow ones flush with frames, which are only 3½ feet wide. It is likely that in the future fire-boxes 5 and 6 feet wide will be more generally used, and with these the grate area will be from 40 to 60 square feet.

The tractive power of freight engines would, in 1905, reach 70,000 pounds and require a weight on drivers of 280,000 pounds, with a total engine weight of 311,000 pounds. With the Consolidation type of locomotive the weight per wheel would then be 35,000 pounds, or two and one-half times the old limits of 1880.

The total heating surface of the boiler would reach 4000 square feet and call for a very large boiler if the present arrangement of heating surface be continued. It is quite probable that as possible limits of width, height, and weight are reached, some change will be made in locomotive boilers so as to include some features of water-tube boilers. In this way increased heating surface may be obtained without further increase in size and weight. It may be also that automatic stokers will be successfully adapted to locomotive requirements, and when such changes occur the locomotive will present a different appearance from that with which we have become familiar.

ENGINEERING GRADUATES FROM UNIVERSITIES

FPOM THE WORKS MANAGER'S POINT OF VIEW

By George W. Dickie, Manager of the Union Iron Works, San Francisco

GRADUATES from engineering colleges contemplating the adoption of the engineering profession in some of its many branches, expect, to reach in it, if not fame and distinction, at least a respectable place, and to secure a fair share of the rewards that are supposed to result from the practical application of that knowledge with which their minds have been stocked from the college reservoirs of science, in carrying out successfully the enterprises that the accumulated wealth of future clients will make possible in engineering development.

Many of the engineering students now entering the profession will, doubtless, take a leading part in future enterprises of such magnitude and far-reaching scope as, at present, to be outside the range of works thought practicable by the engineers of to-day.

New possibilities are continually coming into the field of vision of the engineer, and new powers are being brought within the range of practical things, so that the student entering into active professional work to-day must deal with forces and work with implements that were not within the reach of his predecessors. But there are certain things that he must deal with in his efforts to reach a desirable and comfortable place in his profession that are, and always will be, constants in every problem with which he will struggle. These may all be summed up in one controlling factor, —human nature. This has remained a constant amid all the changes of the past, and is likely to do so in the future, unless something should happen of which there is now no sign.

A young man's university training may have taught him much in regard to physical forces,—how to compute them; how, within certain limits, to

control them, and even to change their character, bringing service out of natural forces that were in opposition. But how to compute the human elements that he must reckon with, how to turn the wild forces of humanity into channels that will run parallel to his works, and add their forces to his efforts in the direction of progress, is a problem outside of the college text-books that requires patience and long experience for even a partial solution.

A young man leaves the university with high hopes of being able quickly to take rank in the engineering profession. His mental equipment is all that could be desired; he is expert in all the computations required to demonstrate the safe or dangerous character of any proposed engineering work; he can use all the delicate instruments of observation and computation required by the engineer; he can construct stress and force diagrams, and knows how to apply them. He is familiar with many studies that I could not mention; for, alas! I am ignorant of many things with which he is quite familiar.

It is natural that this young man, with such a complete equipment, should expect the world to give him some recognition and encouragement when he comes out and offers to use all these acquirements for its benefit, and the disappointment is often very bitter when he finds that the world does not consider itself under any obligation to take the slightest notice of him, or trouble itself about his accomplishments.

This young man, if he be wise, will at once sit down and check off his account with this rough customer of a world, and see how it stands; for the world, though hard, and often slow in settling, is not dishonest. He will probably find, if he makes an honest balance of his account with the world, that he is largely in its debt for the very abilities of which he is so proud. Not one of these accomplishments has he obtained for value given, and before him lie many years of patient work and self-denial before his account can be considered balanced. All his working capital of mental acquirements has been borrowed out of the world's sinking fund of human thought and experience, and until he himself has deposited to his credit an equal amount in that fund the balance is against him, and he cannot rank with the world's creditors. When he has settled this matter as to his standing in the great ledger account that the world keeps with those who work for it, he will be able to start out on a satisfactory footing in his proper place, and though progress may be slow, it will be sure, and, with health and patience, it has every chance of being permanent.

One of the hardest problems the young man will have to struggle with is self. No problem in science, either exact or applied, is so difficult to master as this one. It is ever present, and insists on being attended to, although it is not an engineering question, and has no right to come between him and his professional duties; yet that is just the place it insists upon taking, and if he is not very careful it will keep that place, and cheat him out of every prospect of success.

This question of self is a real question, and a very important question to every one, but it cannot be answered at the beginning of professional life; there are no data then to help in its solution. It takes a whole lifetime to settle it, and in some cases,—and these are the most important ones,—the data are available for a proper and just solution of it only long after the life has closed, so that, however desirous he may be to settle the problem of self at the start, any time spent on it then is time wasted.

A young engineer working in a subordinate position is very apt to compare his abilities with those of his employer or senior in the profession. He is astonished to find how clever he is, compared with those above him in the rank of engineers. He wonders how they managed to get there, while he stays where he is. It hurts him to see the man under whom he serves get all the credit and nearly all the reward for work that he does. He may be working away in a back room, and hear the man he serves discussing plans and methods

with his clients in the front room, explaining, perhaps, some intricate problem that has just been worked out for him in the back room, as if he had done it all himself, as though there were no back room at all, and as though no other brain but his own had been working on the plans in question.

The young man in the back room is apt to resent this, and the natural thing for him to do is to try and prevent this thing from going any further, at least so far as he is concerned. I have known him to resign his place in disgust, and wander about outside, narrating how some one, supposed to be high in the engineering profession, was parading under false colours and using other men's brains to make a reputation for himself. This man may be quite honest about it, and perfectly satisfied that his story is true, and that his treatment has been very bad; but no one will believe him, and he finds himself only laughed at, and fortunate it will be for him if the reception his story gets sets him to thinking, for a little thought may save him at this critical period. Or he may conclude to hang on for a while in the back room, and try to enlighten the clients of his employer as to who it is that is doing the work for which they are so liberally paying another man. So he endeavours, by many devices known in the back room, to bring his name to the notice of those who trust the spending of their capital to the engineer in the front room. Sheets of calculations and plans will appear with the name of our back-room friend on the lower right-hand corner, in order to catch the eye of the man of money, informing him as to the origin of all this wisdom in which he trusts.

Most engineers in the back-room period of their professional lives have gone through this experience, and know how it is. They also know that until the back-room man can overcome this troublesome intrusion of self into his professional work, he is likely to stay in the back room; for it is through the man in the front room that he must work his way to the front.

When I was in the back-room stage of my experience,—in fact, I rather think that my work is still done in the back room,—during this time when I thought that all the work, and none of the honour, went to the back room, I passed through just the struggle I have indicated in trying to solve the problem of self. Now I let it alone, to work out itself.

About twenty-five years ago, when a large and important building was erected in the writer's town, the architect, although a man of some note in his profession, had no experience in designing steel trusses. There was a large open court in the centre of the building, about eighty feet wide, for which a glass roof was required, and the principal owner of the building wanted to make the court and its roof a special feature in the design of the building. I had been doing some designing in steel for this architect, and had noticed that his name always found a prominent place on the plans I had made, and that set me to thinking more on the problem of self than on correct designs.

One day my friend and patron, the architect, came to see me about this roof for the court, and told me that it must be ready on a certain day at ten o'clock, as it was to be presented at that time to his client. Here was a chance, I thought, to solve the problem of self, so far as this case was concerned. So I took care to have my plan ready just in time to hurry with it myself to the meeting; and the most conspicuous thing on that plan was the name of the designer. The architect had no time to look at it before rolling it out before his client. I never knew how he behaved under such embarrassing conditions, as he never mentioned the matter to me.

The plan was approved and carried out, and looks well to-day. The client, however, sent for me the next day, and simply asked me if I took him for an ignorant ass to think that he did not know where his architect had his engineering jobs done.

"Now," said he, "I designed that roof myself; you simply put my conception into a working drawing to guide the mechanic in getting it into shape.

If I had not thought of that roof and planned to have it there you never would have drawn a line in connection with it. Young man," he added, "I have known you for some years, but did not suspect that you would try to introduce yourself in that way where you were already known."

This result from that effort to solve the problem of self did not please me at the time, but it looks nearer correct now than it did then.

The young engineer will encounter this problem of self under many and varied conditions, and will be deceived by many false equations in his efforts to solve it. A desire to be noticed and talked about is made a prime factor, and appears in the equation as ambition. This element is sure to bring out a false result. Ambition is a powerful factor in the life of an engineer or any other man who is trying to accomplish something; but there is a false ambition that hinders a man as much as the true ambition helps him. He will need to be careful not to fall into the general error in regard to ambition. His aim should be to do some good and useful work, instead of scheming to be considered great and indispensable. Great men are such because their work has lifted them up above their fellow-workers, and not because they walk on stilts. Great men are not ambitious in that way. It is the little men in every profession that use stilts. No great man, nor any true man, although not very great, who had any real substance in him, could ever be troubled by that kind of ambition.

The engineer's ambition should be to put the very best he knows, and the very best he is, into his work, and whatever place that kind of work may reach in the estimation of his fellow-men, there he can honestly stand beside it, and that is the only safe place to stand.

While the young engineer at the outset of his professional life cannot solve the problem of self, he must also be careful not to lose self altogether in the practice of some special branch of engineering. There is great danger of this, in the stage of development reached by the art of engineering in these days, when a man is expected to be an acknowledged expert in one or more branches of his profession.

In the effort to master thoroughly some chosen branch of engineering everything that a man might know or do, with great advantage to himself in life, is often sacrificed, and the man becomes one-sided, every power of mind he possesses being diverted into one channel; he becomes narrowed down to the width of that channel; his mind becomes dwarfed in every dimension save one.

To my mind, a complete man should be larger than any profession; yet some men try to squeeze their whole being into some single branch of a profession, and instead of their having a profession, in the practice of which they can earn a good name and an honest living, the profession owns them body and soul, and outside of its narrow limits the man is no better than a stick.

Here I think the university man, if he be true to himself and to the broader culture that is within his reach, has the advantage of those who, in their young days, had to struggle for knowledge and work for bread at the same time. No one will suffer, even as a special expert, by having a general knowledge, not only of his own profession in all its branches, but of the world also, and human life in all its varied aspects and experiences.

Perhaps there is no class of professional men so separated from their educated fellow-men by the requirements of their work as engineers. Professional men generally look upon the engineer as hardly within the charmed circle of the learned professions, and only reluctantly give place to him. The engineer himself is partly to blame for this. He finds that, outside of engineering circles, his special studies, and his handling of material things, are not considered to be the best things to develop the nobler part of the man. The highest he can reach in engineering practice may reach the pockets, but he will never touch the hearts of his fellowmen. They may need his help to carry

out some scheme of material improvement, and will pay him just enough to secure his services, but for the man himself they have no use.

The engineer of to-day requires a broader culture. Whatever leisure the practice of his profession allows him should be devoted to other studies, and these, I think, should be of a social character, as better fitting him to take his proper place amongst his fellowmen. There are some engineers who have followed such a course, very much to their own advantage as men, and very much to the pleasure and profit of all those who know them intimately. I would, therefore, warn the young engineer not to let himself be buried under any kind of engineering structure, no matter how great a piece of work it may be. Build such structures, certainly, and build them well; but stand on the top of them, and show to those about you that the man is always better than his work, even if that work is engineering.

Another difficulty likely to beset the young engineer is in finding a job big enough to correspond with his own estimate of his abilities as an engineer. It is a good thing to have high aims, and a proper estimate of what one could accomplish; but I have never yet found any one willing to entrust me with the doing of anything big enough to meet my ideas of what I could do if given the opportunity.

When the young engineer has made his plans for life, and has decided on some important work of great utility that needs to be done, and has pictured to himself what a grand thing the consummation of such a grand work would be for the State or city in which he lives, and what satisfaction he would have in devoting his life and all his ability to its successful accomplishment, he has done the right thing; but he need not expect that he can reach even the beginning of any such enterprise, except through the doing, and doing well, of many little jobs that cover the whole field between him and the great work upon which he has set his heart. Yet he should never lose sight of the one thing that inspires him, but study it from every side, let every little job he does add to the needed experience for the chief work in his mind, gathering mental materials for it from everything that comes in his way, and some day, when he is well fitted to do this thing, it will enter into the head of some men with the faculty of combining capital and inspiring confidence to do this very thing. Then the engineer, perhaps no longer young, but with gathered experience and known knowledge of all that is needed to carry such an enterprise to successful completion, will be sought out and placed in charge, not because he conceived of such a thing when he started out from college, but because he nourished that conception of his, and turned every opportunity he had into experience with which to strengthen his purpose and ripen his judgment, so that when the thing was born he could father it to some purpose.

He must never lose sight of his conception, while at the same time he does the very best he can on whatever comes to his hand or head to do. Some day the grand idea will take shape, and he will be glad that it did not come before he was ready.

Another thing I would like to speak about to the young engineer; but considering that he has just graduated from a university, I must do it gently. When he goes out to take his place among engineers he will meet with many able men, who are entrusted with great interests, and whose reputation extends over a whole country, and he will be surprised to find that they have forgotten many of those things by which he sets great store. Perhaps they never knew them by the names and titles known to him, and he cannot understand how they manage to carry on great works without the knowledge he is so proud to possess. After he has gone a little farther on in his engineering experience, he may possibly find out that these men have become so intimate with those things whose titles are so familiar to him that the titles have all been forgotten in the familiar intercourse of every-day practice.

He will find many men,—and be able

to learn much from them if he is not too proud of what he already knows,—who have a very intimate acquaintance with the things themselves, while he only knows the symbols that represent them in books. All the collected formulæ that were so difficult to learn and understand he may have to abandon when he becomes acquainted with the things themselves, for he may not meet them under the same conditions or in the same company as the man met them who prepared the formulæ by which he was first introduced to them.

There are so many ways by which men learn to know things that I would not advise the young engineer to be too sure that the way by which he was led up to any subject is the only way by which that subject may be reached. His text-books may be right enough, and the more thoroughly he knows them the better; but he should never let them stand between him and the thing itself of which they treat. The text-book is his introduction into the society of material things, but when once he has become intimate with those things, and has managed to enlist a number of them in his service, introductions by formulæ in dealing with them are no longer necessary, for even natural laws seem to know what an intimate friend expects of them, and act accordingly.

This is true, and I mean the young engineer to take it seriously. Natural laws are apt to be suspicious of a man who always needs formulæ introduction and never gets on friendly and intimate terms with the great forces about him. How can he get the best service out of these forces if he cannot get any closer to them than the book allows?

Let him get on intimate, friendly, speaking terms with all the physical forces about him, especially those he needs to work for him so that he can see this very thing itself, that will work for him if he can use it, or against him if he cannot make friends with it. He must not allow even the thickness of a single leaf of a book to get between him and the things with which he works.

THE COST OF MACHINE WORK

By Francis H. Richards

THE question as to the "cost" of a machine, or of the product turned out by it, involves a number of items, at least one of which is frequently too little considered. Of course, it is well known that when a new machine is once put into service it immediately becomes "second-hand," thus entailing an immediate loss in market value. The longer the machine is in use, and the less carefully it is treated, the more rapidly it depreciates, and the extent of the depreciation, whether it be much or little, must be considered in estimating from time to time the present value of the machine. Similarly, the cost of maintaining the machine in a sufficiently good condition to insure its efficiency is an item which cannot be overlooked.

There is, however, another item, which, in many cases, is of even greater importance. A manufacturer obtaining a new machine, especially if it is designed for some work for which there is a limited market, stands, in these days of rapid improvement and development, face to face with the question, "How long before the machine must be supplanted by a better one in order that I may compete in cost of product with others who may at some time obtain a more efficient machine for doing the same work?" In other words, what is the percentage of the hazard of being compelled to abandon the machine and

procure another of later improvement in order that he may maintain his market, or may continue to make a profit on his manufactures?

Even the most casual glance at the history of special machinery, as employed in American manufactures, for example, during the past two or three decades will show that this "risk," as insurance people would term it, is by no means a small one. It is a question if the majority of standard machines can be used profitably for a period of twenty years, even if maintained in a perfectly efficient condition. Indeed, it is a question if any machines, in such a sense, are strictly standard. Clearly the majority of the machines in use are to a certain extent special, and the more rapid the improvement in any particular art, the more rapidly the machines become relatively inefficient, as measured by their earning capacity.

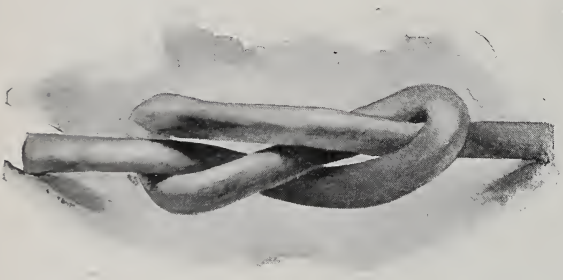
A somewhat extended observation in this line leads the writer to believe that ten years is, at the present time, a high average for the life of automatic machinery generally, when considered from this point of view. Suppose, for instance, a manufacturer has the opportunity of obtaining a special machine ten years old for an extremely low price, or of paying a relatively high price for the latest improved machine for the same purpose, which one is the best for him to buy? Usually the latest and best will be found the cheapest. A small advance in output, quality, and economy of labour more than offsets a very large difference in first cost.

Current Topics

An interesting illustration of the well-known fact that a boiler can have more heating surface than is good for it, was cited recently by Dr. Coleman Sellers in a lecture before the Franklin Institute. When the first large engines and boilers for the water works of the city of Philadelphia were installed a great many years ago, it was found, upon test, that the boilers were insufficient for their purpose. Oliver Evans, who had designed the engines, had specified the length of the grate bars and the width of the furnace to be used, as also the length of the boilers, which were of the plain cylinder type; but the wise men of the city government believed that they could do better by making the boilers much longer than he had suggested, and they were so constructed. Upon their failure to do the work, Oliver Evans was sent for in haste to correct the difficulty. His message to those in charge, enforced by his presence afterwards, was that they must cut off 10 feet from the length of each boiler. This seemed a strange proceeding, but he soon explained to

them that the extra length which they had added to his prescribed dimensions was acting as a condenser to re-convert steam into water, inasmuch as the heat of the furnace could not extend the whole length of the boilers as they had been built. Upon cutting the boilers down to their proper size so that the heat could extend over the whole fire surface, they proved sufficient for their work, and continued to operate as long as this primitive water plant was in existence.

A CURIOUS freak, recently observed in connection with the working of a copper furnace, is illustrated in the appended sketch. This has been reproduced from the *Engineering and Mining Journal*, to which a correspondent has given also the following particulars: —The furnace in question had been banked for twenty-four hours, and



A CURIOSITY IN BLAST FURNACE PRACTICE

shortly after the blast was turned on it became apparent that some obstruction about mid-length of the furnace prevented a free flow of slag to the tap hole, it being forced to flow through the back tuyeres. To remedy this a long rod of 1-inch round iron was rammed in by the combined efforts of four men. On attempting to withdraw it, it was found necessary to use a dog and wedge, and even then very considerable difficulty was experienced in getting it out, and the superintendent, who happened to be present at the time, remarked to the foreman:—"You surely have got a knot on the end of your rod, Jack," yet little expecting to see his surmise so marvellously borne out in the mass of slag and iron which eventually came out on the end of the rod. The sketch shows the knot exactly as it came out of the furnace, being cut off from the long end of the rod at the left, and the adhering slag knocked off. The right-hand end was the one driven into the furnace. The total length of the knotted rod was 16 inches.

THE time when the standard American passenger locomotive was resplendent in bright paints and polished brass is not so long ago that it is not clear in the memory of men of middle age. The transition to the present businesslike appearance of the engine was a rapid one, and the expense item involved in the decorative features of those earlier days of locomotive engineering has been cut down to represent simply the requirements of good service, and, happily, good taste as well. The extent of this change is well shown in some of the illustrations in the article entitled "The Increasing Size of American Locomotives," printed in this issue. The Chicago & North Western locomotive, for example, shown on page 147, cost $40,000, and of this sum $2300 were expended for painting alone. The portrait on the headlight was that of a former president of the company. The sand-box and the standards holding the bell, as well as all the dome rings, were of solid brass, hand finished. To-day substantial simplicity is the rule.

THE steamer *Deutschland*, of the Hamburg-American Line, which will make its first trip during the present month, will, if everything turns out as expected and guaranteed, be the fastest transatlantic liner now afloat. Twenty-three knots, equivalent to about 26½ miles, are to be the average hourly speed across the ocean, and that means that she will easily beat the record of the North German Lloyd steamer *Kaiser Wilhelm der Grosse*, which has to it credit a maximum of 22.63 knots, o

a very small fraction over 26 miles an hour. But, according to latest accounts, these remarkable performances are to be totally eclipsed by a new ship which the North German Lloyd Company is said to be getting ready to build, and which, in point of size, too, will go beyond anything hitherto in service. Seven hundred and fifty-two feet are to be the length, and twenty-four knots, or 27.6 miles, the minimum speed of this vessel, and her indicated horse-power is to run up into the neighbourhood of 40,000. Five days and seven hours will be the time of transit between Southampton and Sandy Hook. It is worth noting, apropos of this, that only a few years ago the Atlantic express steamer was declared to be an unprofitable adjunct of the steamship business, and that before long there would be a settling-down to the building of moderate-speed ships of large carrying capacity, from which alone satisfactory financial returns could be expected. That there is a maximum efficiency combination of steaming speed and useful carrying capacity which is considerably at variance with what is found in the so-called Atlantic greyhound, has been pretty well determined; but, after all, the matter of profitable running is simply a question of rates for carriage, and these rates on the highest speed ships evidently are high enough and are paid in sufficient numbers to make the ships profitable. At any rate, the development of the ocean express service is going on apace, and what were once considered wild predictions of 1000-foot steamers and 30-knot speeds across the Atlantic now appear to be pretty close to realisation.

It may seem anomalous to speak of electricity as a bye-product, and yet such it is in the operations of the Toledo Heating and Lighting Company, at Toledo, Ohio, U. S. A. In the May number of this magazine, in an article devoted to "Electric Central Stations and Isolated Plants," the point was made that the commercial salvation of the electric central station depended, in a great measure, upon a satisfactory distribution of its large heat product, quite as much, indeed, as upon the disposal of its relatively small electric product, and that so long as the lion's share of the station energy was allowed to escape as waste heat, just so long the station would be unable to compete with the service of the electric isolated plant in which heat wastes had been reduced to a practical minimum. It is upon this basis that the Toledo enterprise is being conducted. According to particulars which have been given of it by Mr. H. T. Yaryan, one of its engineers, in a paper read during the past month before the American Society of Mechanical Engineers, the system, which, by the way, appears to have been in successful operation for the past five years, utilises all its exhaust steam for heating water which subsequently is circulated through a territory measured by a radius of a mile and a half from the station, heating dwelling houses and other buildings. The fuel cost of the electricity, which is generated as an incidental, is simply that required to make up for the condensation in the engines.

The system comprises steam boilers, engines, and dynamos such as may be used in the ordinary electric light station. Heaters of the tubular type, through which the water passes from the pumps to the mains, receive the exhaust steam from the engines, heating the water to any desired temperature. When more exhaust is being produced than is required to heat the water, the excess is delivered to a water-storage tank, to be used later when the output of electricity is small. The circulating system consists of two wrought iron pipes, laid side by side in the ground, carefully protected by insulation, one pipe for the outflow of hot water impelled by the pumps, the other for the return water from the coils in the various houses heated, going back to the suction end of the pumps, to be forced again through the heaters, where the

loss in temperature is restored. There are two stations, and although the heating mains of these are separate and distinct, their dynamos feed into a common system of electric mains. The total number of buildings heated is 199, there being somewhat over three miles of double hot water mains, supplying 175,000 square feet of radiating surface.

THE loss of heat through radiation in the mains is an important one, estimated at about 15 or 20 per cent. The water reaches the extreme ends of the lines, three-quarters of a mile from the stations, with a loss of 12 degrees Fahr. in the coldest weather. A pressure of 60 pounds is maintained on the feed line during cold weather and 40 pounds during moderate weather. The service pipes to the various houses are 1-inch pipe, and the return line is throttled with a disc inside the building, the size of opening depending upon the quantity of radiation, but averaging five-eighths of an inch. The houses are equipped with radiation sufficient to heat them to a temperature of 70 degrees Fahr., with water entering the house at 160 degrees Fahr., when the outside temperature is freezing. By raising or lowering the temperature of water one degree for each degree of variation in the outside temperature, a constant temperature is maintained in the houses during all kinds of weather. The extreme limits of temperature of the water are from 130 degrees in moderate weather to 212 degrees in the coldest. As a matter of additional interest in connection with this it is worth noting that during the coming summer the company propose installing a refrigerating plant for domestic use, to distribute cold brine in exactly the same way that they now distribute hot water, but using a separate set of mains. An ammonia absorption machine is to be used, operated with the exhaust steam from the station engines, so that as the demand for heat ceases, that for cooling purposes begins, thus utilising the exhaust during the summer months when formerly it went to waste.

EDWARD DANIEL MEIER

A BIOGRAPHICAL SKETCH

By Robert W. Hunt

THE question has been often asked, —"How and why have the United States of America made such wonderful progress, and in so short a time?" The answer is simple, when we study the character of the men who have been active in its affairs. With such citizens any country must have prospered; and when such men have had such a country for their field the result was certain to be—America!

Colonel Edward Daniel Meier was born in St. Louis, Mo., in 1841. After attending local schools for five years, he was sent by his father, Adolphus Meier, to Bremen, Germany, where he studied for one year, returning to St. Louis in 1853, and there prepared to enter Washington University, St. Louis, which he did in 1857, taking a special course of one year. In 1858 he entered the Royal Polytechnic School at Hanover, Germany, and, after a four years' course, came back to America, in 1862, and began practical work as an apprentice in the William Mason Machine Works, at Taunton, Mass.

The Civil War was raging, and the call to arms was too imperative for him to remain in civil pursuits. The Confederate army was making its determined advance on the Northern States, and young Meier enrolled himself as a private in the Thirty-second Pennsyl-

vania Militia, best known as the Grey Reserves. He, with his regiment, joined the Army of the Potomac at Hagerstown, Md. The Union victory at Gettysburg compelled the retirement of Lee's army to Virginia, and the emergency troops were sent home. But he was not satisfied with so short an army experience, and soon enlisted in Nim's Second Massachusetts Battery. With it he was in skirmishes at Opelousas, Cane River, Alexandria, and other places, and in the two days' battle of Sabine Cross Roads during the Red River campaign. Later, he was detailed to the U. S. A. Engineering Corps, and put in charge of one section of the work of fortifying Camp Parapet, extending from the Mississippi River to Lake Pontchartrain, above New Orleans, and afterward on the survey of a line of works at Brashear City, La. Following this, he was promoted to a Second Lieutenancy in the First Louisiana Cavalry, and, as such, saw duty in many raids and skirmishes, which resulted in his being made a First Lieutenant and aide-de-camp on the staff of General J. W. Davidson, then commanding the cavalry corps of the Division of West Mississippi. Lieutenant Meier was given the command of a raiding party into Tensas Parish, Louisiana, and on May 30, 1865, had the honour of receiving the surrender of the Confederate Lieutenant-General John B. Hood and three members of his personal staff.

The war ended, Lieutenant Meier, after being mustered out of service, at once took up his chosen calling by obtaining employment in the Rogers Locomotive Works, at Paterson, N. J., as a finisher and draughtsman. There he remained for about a year. In 1867 he was appointed Assistant Division Superintendent on the Kansas Pacific Railroad. During this service a blizzard carried away the railroad bridge over the Republican River at Fort Riley, Kansas. Mr. Meier was put in charge of the situation, making his headquarters in a box car. He obtained a pontoon bridge from the U. S. A. quartermaster at Fort Riley and bridged the river, over which he transported quartermaster's stores, passengers, mail, and express matter for several weeks; but as there was a flood in the river, he was compelled to take up the bridge each night, relaying it again in the morning. The weather was intensely cold, and all the hands employed suffered severely.

In 1868 he designed, built and operated a stone working mill at Junction City, in which was planed and turned the soft magnesian limestones of the Smokey Hill Valley. Later in the year he designed shops for the railroad, which, owing to financial troubles, were not completed. But, some time afterwards, the plans were used for the shops located at Moberly, Mo.

During 1869-70 Mr. Meier was the superintendent of machinery of the Kansas Pacific Railroad, but early in 1871 his health gave way from overwork, and he resigned, afterward making a trip to Europe. During this he could not be content to be entirely idle, and so spent much time in studying the European developments of coal washing and coking. On his return to America he became connected with the Illinois Patent Coke Company, which had already built works at East St. Louis, Ill. Colonel Meier's father was largely interested in these works, and his elder brother, John W. Meier, was the engineer in charge. Their efforts to produce a satisfactory coke from the Big-Muddy coals were satisfactory, but after the expenditure of over one hundred thousand dollars the attempt was abandoned, owing to the panic of 1873. But their plant and efforts were fully up to the then known state of the art; in fact, it was the commercial, and not the mechanical, side of the enterprise which failed.

Mr. Adolphus Meier was greatly impressed with the advantages of St. Louis as an iron centre. At that time the Iron Mountain district of Missouri was believed to contain a practically inexhaustible supply of high-grade iron ore. He subscribed liberally of his own means, and enlisted German capital, and organised the Meier Iron Copmany, which built two blast furnaces at Bessemer,

Ill., not far from St. Louis. Colonel E. D. Meier during 1873-74 was actively employed by this company in laying out their railroad system, foundations, etc., and was in charge of much of their mechanical construction. It was at these blast furnaces that the first fire-brick hot blast stoves west of the Alleghenies were erected.

During 1875-76-77 Mr. Meier was connected with the St. Louis cotton industry as mechanical engineer. From 1878 to 1884, inclusive, he was the manager and secretary of the Peper Cotton Press Company, of St. Louis, during which time, in addition to other large work, he designed, patented and built a hydraulic press of great power and capacity.

Colonel Meier later became impressed with the advantages of the water-tube boiler system, and his European connections brought him in contact with Heine and his boiler of that type. This led, in 1885, to his organising the Heine Safety Water-Tube Boiler Company, and he has been its president and chief engineer ever since. During this time he made several improvements on the original system, and the company has been successful, both pecuniarily and technically.

To a man of Colonel Meier's great energy, however, the duties of one company organisation were not enough; hence, during the period since 1885 he has been engaged in many other engineering duties, among them having rendered efficient service as secretary of the American Boiler Manufacturers' Association, and as chairman of its committee on materials. As such he was practically the author of both the first and second sets of specifications which were adopted as the association's standard, and are so recognised by the boiler manufacturers of the United States. In the fall of 1897 he visited Germany professionally, to examine and report on the Diesel motor. This resulted in the organisation of the Diesel Motor Company of America, with Colonel Meier as chief engineer, which office he still holds.

During the railroad riots of 1877 Colonel Meier organised a battalion of militia to guard the St. Louis Water Works. From this nucleus was formed the Third Regiment National Guard of Missouri, with him as lieutenant-colonel, and later, when it was consolidated with the First Regiment, he was unanimously chosen colonel. The officers of the brigade joined in recommending him for the position of brigadier-general, but he declined, preferring to retain the personal command of his own First Regiment, and, as ranking colonel, the command of the First Brigade National Guard of Missouri. He resigned from service in 1887.

Colonel Meier is a member of the Grand Army of the Republic and the military order of the Loyal Legion. He has been active in many other public ways than as a military man. He is a member of the St. Louis Engineers' Club, and was its president. He is also a member of the American Society of Mechanical Engineers, and is now one of the vice-presidents of that organisation. He is also a member of the American Institute of Mining Engineers and of the American Society of Naval Engineers, and has contributed liberally to the proceedings of all the societies, in addition to bringing out several scientific works.

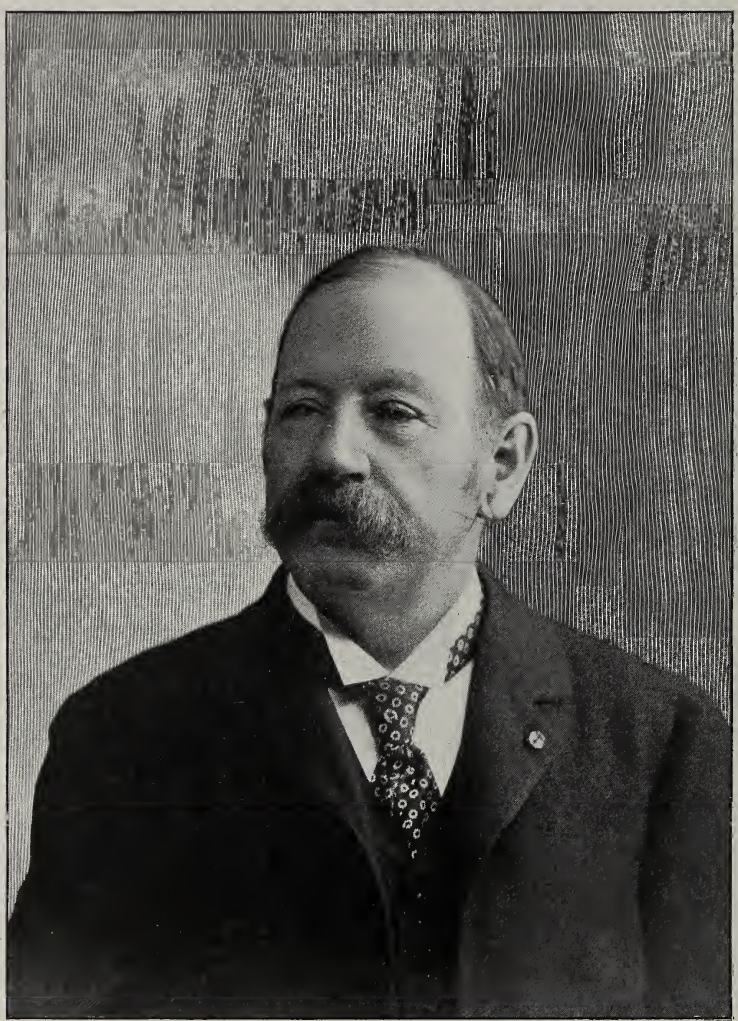


PHOTO BY BUTLER, BROOKLYN, N. Y.

Chas H. Loring

CHIEF ENGINEER UNITED STATES NAVY, RETIRED.

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CASSIER'S MAGAZINE

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MAKING "BEST YORKSHIRE" IRON

By Ewing Matheson, M. Inst. C. E.

ROLLING BARS

DURING the last fifty years the methods of manufacturing iron have been continually improved, but while examining these changes, as well as those attending the transition to steel, it is interesting to take note also of those older methods and processes which still remain, and to consider why they survive.

Great Britain has, for two thousand years, been an iron-making country, for iron implements were in use at the time of the Roman invasion, and from then till long after the Norman conquest the methods adopted for separating the metal from the ore and making malleable iron probably resembled those which still prevail in Central Africa, and were in use till the last century in Spain also. The ore, having been first roasted, was broken into small pieces, and then was melted by one or more operations of heating by wood or charcoal, the fire being stimulated by bellows, or, in some cases, by an induced current of air through flues converging into a central hearth or furnace. What is known to metallurgists as the Catalan forge may still be found in Spain and elsewhere. Even where the ore was not thoroughly

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RUNNING PIGS FROM A BLAST FURNACE.

melted, it was heated to such a plastic condition as to allow the earthy and other impurities to be hammered out in the form of cinder, and by a lengthened treatment of this sort the iron was decarbonised and became malleable, or wrought iron.

The good quality of the iron so produced was due to two main causes, the first being that the ore found amenable to this treatment was rich, and the second that the wood or charcoal used as fuel was free from sulphur. The iron made in Spain, from which, by a subsequent process, the famous Toledo steel was produced, was probably all made from hematite ore, very low in phosphorus, and of the kind still mined in large quantities in the north and southeast of Spain, as well as on the northern coast of Africa, for use in British, German, and American steel works.

It is unnecessary here to do more than mention the three salient points on which modern iron-making depends:—The introduction of fossil fuel or coal in the seventeenth century by Lord Dudley; the invention of puddling by Cort, in 1783, for the easier conversion of cast into wrought iron; and the most important modern improvement, the invention of the hot-blast by James Neilson, who obtained his patent in 1829. This latter invention effected not only a saving in fuel, but a greatly increased production of iron in a given time.

In America, iron making began in the early colonial days, and from 1720 onward there was a regular and growing export of pig iron to Great Britain, so that in 1775, when the American war of independence broke out, about 4000 tons per annum were being shipped. This was due mainly to the abundance of wood for fuel. The present famous Cambria Works at Johnstown, Pennsylvania, are in the district from which, one hundred and fifty years ago, iron was brought by road and canal to the Atlantic coast. The abundance of wood for smelting simply exemplifies the condition that has attended iron making in

all ages and countries, namely, that it is the presence of fuel rather than iron ore that determines the locality of melting.

Scandinavian forests encouraged iron making in Sweden, and the highest quality of charcoal iron is regularly exported to Sheffield as material for steel. In England, the counties of Sussex and Gloucestershire were the favoured localities, and at an even earlier date iron was made in Ireland. As, however, it is only where coal is abundant that iron making can now flourish, the use of charcoal fuel has almost died out; even in Sweden coal is imported.

The introduction of the hot-blast did not improve the quality of the pig iron, and the slower and more expensive process of smelting by a cold blast of air is still carried on, the present extent of it having been arrived at, through a natural evolution, by the needs of engineers for a particular quality of iron. Notwithstanding the general adoption of the hot-blast there are still about ten cold-blast furnaces working in England, these being situated in Yorkshire, Staffordshire, Shropshire, and South Wales. It is only those in the first-named county which are here dealt with, as the pig iron made elsewhere is used for other purposes than that which forms the subject of the present article.

About the year 1850 there was fully established in the West Riding of Yorkshire, near the towns of Leeds and Bradford, a considerable industry in the smelting of cold-blast iron, the pig iron so produced being used mainly in the manufacture of finished wrought iron.

PUDDLING

The furnaces and rolling mills at Farnley, near Leeds, as also those at the Lowmoor and Bowling ironworks, near Bradford, became known far and wide, and it was the custom of engineers in those days to specify these three names or brands under the general appellation of "Best Yorkshire" iron when high-class material was required for any particular purpose.

The Bowling furnaces no longer exist in connection with finished iron, but the following description of the Farnley Iron Works, as carried on at the present

REFINING THE PIG METAL

time, may prove interesting, the more so because they are entirely unlike those in which the bulk of the iron in Great Britain is made. The works are situated about three miles from Leeds, on a site chosen because iron, coal, and fire-clay are mined there. The clay-band ironstone, or ore, is found in the form of nodules lying in shale immediately above the coal, and contains about 33 per cent. of metallic iron. The ore, after it has been brought to the surface, is left for some months in heaps to "weather," so as to loosen or disintegrate the shale which surrounds it, and which is then broken away by hammering, or "knapping." To still further reduce the shale, the ore is then burnt or calcined. Formerly this was done in open heaps; now the ore is burnt in a cylindrical calcining furnace, but in either case a very slight amount of waste or small coal is required.

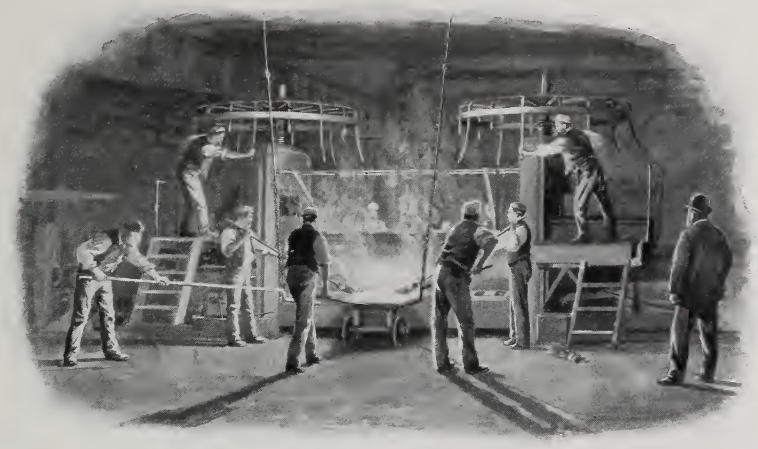
The Farnley works are situated on sloping ground, so that as the ore and coal arrive at the upper level, as shown on page 184, the products descend at each stage to a lower level, so avoiding the necessity for hoisting. The coal is of too soft and bituminous a nature to bear the burden of the ore without crushing and caking, and it is necessary, as in the majority of ironworks everywhere, to coke it. The coking ovens are on the same level as the top or mouth of the blast furnace, and at this, the first contact with fuel, one important condition is necessary, namely, that the coal shall be free from sulphur. The coal used is known as "Better-Bed," which is the local geological name given to the seam from which it is mined and which lies about 100 feet above the "Black-Bed" seam, the coal in this lower level being used mainly as steam-boiler fuel and for other purposes where purity as to sulphur is not of the first importance. About 44 cwts. of ore, 30 cwts. of coke, and 11 cwts. of limestone are the quantities and proportions necessary to produce one ton of pig iron.

The furnaces are built of stone lined with refractory bricks made of Farnley fire-clay. This fire-clay, found in contiguity to the "Better-Bed" coal, exists in large quantities in and about the city of Leeds at depths ranging from the outcrop on the surface to 150 feet below, the clay from the deeper seams being as hard as rock when mined, and, when ground and made into bricks, proving the most refractory against the

action of fire. It is for this latter reason that the numerous firms established at Leeds for utilising this clay in the manufacture of glazed or enamelled ware find a preference in London and other places for their glazed bricks which are seen in such large quantities in the walls of narrow alleys and courtyards where the maximum of light is required, or in lavatories and hospitals where a glazed surface is desirable for sanitary reasons. The great fire resisting quality of the fire-clay allows a hard enamel or glaze to be used which requires a very great heat to melt it, a glaze which is more durable than those softer glazes which melt under a lower heat.

At the Farnley Iron Works a blowing-engine forces the air, at a pressure to iron founders, though its high price at present, from £7 to £8 per ton,—more than double that of the best Scotch pig iron,—necessarily limits its use. The pig iron is strong and tough, with a close grain, and foundry test-bars made from it, 2 inches deep and 1 inch wide, placed on bearings 3 feet apart, will sustain from 30 to 32 cwts. before breaking.

The next stage in the manufacture is to remelt the pig iron in open fires, as shown on the opposite page, with the same kind of coke as has been used in the blast furnace, stimulated by a blast from converging air-tuyeres, this being a process entirely wanting in the manufacture of ordinary iron where the pig iron goes direct to the puddlers.

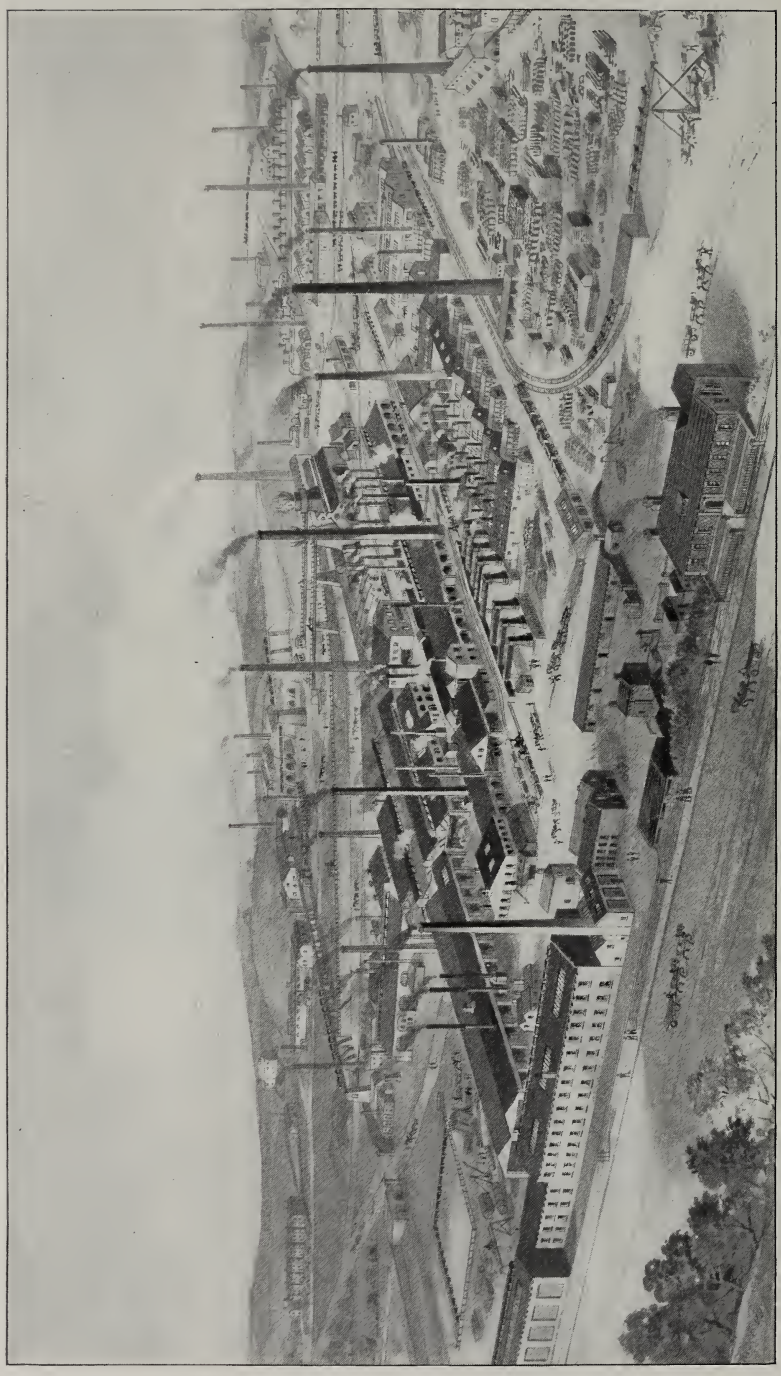


IN A PLATE MILL

of about 3½ pounds per square inch, into the blast furnace through three tuyere nozzles. There is a marked absence of the heating stove which, in ordinary blast furnaces, is used to raise the temperature to not less than 1000° Fahr., and the low-pressure cold blast, though sufficient to stimulate combustion to a melting point, takes out only the best of the iron, much of what usually goes into hot-blast pig iron passing into the slag or dross. The cold-blast pig smelted at Farnley, though chiefly used as a material for making into finished iron, is supplied in small quantities also

The refined iron is run into shallow iron moulds, and, when cold, has a bright fracture much resembling "spiegel" in appearance. The refining rids the iron of silicon and slightly reduces the carbon, thus bringing it a stage nearer to wrought iron.

The refined iron, having been broken, is taken to the puddling furnaces (see page 181) where, being again melted, this time with coal instead of coke, it is stirred by the puddlers till the carbon is entirely removed. Till that period arrives, the metal remains liquid, but as the carbon passes away, the iron will



A BIRDSEYE VIEW OF THE WORKS OF THE FARNLEY IRON COMPANY, LTD., AT LEEDS

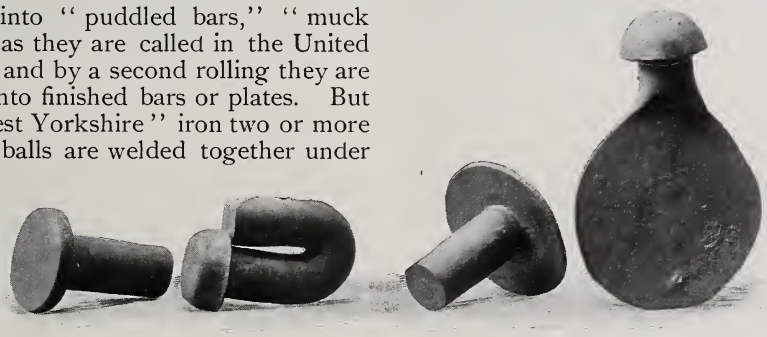
no longer flow; it becomes plastic or spongy, and is, chemically, now pure wrought iron, and in that condition it is gathered into two or three balls which are taken immediately to the nobbling hammer, where by blows, gentle at first, and afterwards severe, they are compressed into rectangular lumps, the hammering driving out of them the foreign matters they have acquired during their contact with the coal and furnace.

The original charge of refined iron was about 336 pounds, and the weight of each hammered ball, of which there are two or three per heat, varies from 90 to 160 pounds. In the case of ordinary iron the balls would be at once rolled into "puddled bars," "muck bars," as they are called in the United States, and by a second rolling they are made into finished bars or plates. But in "Best Yorkshire" iron two or more of the balls are welded together under the steam hammer, as shown on page 186, and are then reheated and forged into blooms from 4 feet to 5 feet in length and weighing from 160 to 300 pounds. These are rolled down into bars, which are cut up and piled together and again hammered into blooms, or, if for plates, into slabs. The final operation of rolling down to a plate or bar of the desired dimensions then takes place, as shown on pages 179 and 183.

By the above method, of beginning with the best ore and pig iron and following by elaborate processes of refining, hammering, and rolling, the plates and bars produced have not only a toughness and ductility otherwise unobtainable, but, owing to the repeated operations, there is the least possible risk of defects or impurities remaining hidden. It is because of this certainty and uniformity of quality that the iron is chosen for those purposes where the cost is of secondary importance. Notwithstanding the great advantages afforded by steel,—strength, ductility, and cheapness,—iron boiler plates still are in occasional demand where long endurance is desired, where great heat and fluctuations of heat have to be borne, where, owing to bad water, there is a special liability to corrosion, and where, during the lifetime of the boiler, mending or patching may become necessary. High-class iron is safer and easier to work than steel for this latter purpose.

While the large diameter and high pressure of marine boilers render steel absolutely necessary for the plates, and while the strength, ductility for working, and cheapness of steel have caused its adoption also for locomotive and stationary boilers, the period which has elapsed since steel boiler plates were first used, say, twenty years, is only now affording a long enough series of results by which to measure the merits and economies of the two materials. Steel is used in the great majority of cases, but if the cost of renewals and repairs be taken into account over a term of years, "Best Yorkshire" iron is still claimed to be preferable by those who advocate its use. Where boilers have to be patched or mended far away from engineering workshops, the iron is more easily treated than steel.

If a sample piece of plate which has been torn asunder in the testing ma-



COLD TEST HOT TEST

RIVET TESTS MADE WITH "BEST YORKSHIRE" IRON

HAMMERING BLOOMS

chine be carefully examined at the place of fracture, there will be seen in a thickness of, say, three-quarters of an inch, as many as thirty lines where the numerous pilings have been welded and rolled together. Any surface damage or crack that may occur to the plates when in use, or any corrosion of the surface will not spread through the whole thickness, as happens in steel rolled out of a homogeneous ingot, which has been cast in a mould, but will have, to use the words of the late Dr. Siemens, "to take a new departure" at each line where the film-flux of the weld has to be passed through.

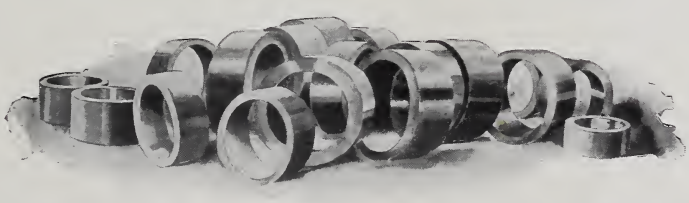
TEST PIECES SHOWING "BEST YORKSHIRE" IRON TWISTED AND OTHERWISE DISTORTED

"Best Yorkshire" iron bars are used for such purposes as the draw-hooks, links and shackles of railway trains which are subjected to a rapid succession of shocks, because such iron is not only tough, but is less liable than steel to become,—as all iron or steel does eventually become after an infinite number of such shocks,—crystalline and brittle. Notwithstanding its high cost, at present about £20 per ton, as against £10 for Staffordshire bars, the iron is used in this way on all railways in Great Britain, India, and the British colonies. The connecting rods, coupling rods, and piston rods of locomotives are also advantageously made of this iron, as also the frames, safety-hooks, and other suspending parts of cages in mine shafts where life is at stake, and by engineers generally for important parts subject to severe shocks and for forgings that have to be welded. In the operations of the blacksmith there is much more risk of failure in welding steel than iron, and, as an extreme case, it may be said that it is for the reason that every link has to be welded that chains of steel are practically unknown to commerce, not-

withstanding the great inducements afforded by the lightness, strength and cheaness of that material. While steel is now supreme for the majority of purposes, there is more "Best Yorkshire" bar iron made at the present time than has ever been the case in past years. Besides the Farnley and Lowmoor companies who carry on all stages of the manufacture from their own minerals, there are two other firms, Taylor Brothers and the Monkbridge Company, who, at Leeds, also manufacture and supply the same high-class iron.

In the United States there is one use for high-class iron which does not arise in Great Britain. The short stay-bolts which, in locomotives, attach the fire-box to the outer shell, are subject to peculiar bending and twisting strains, and are liable to break, the thread on the bolt affording a vulnerable nicking for the fracture. On British railways the fire-boxes are always made of copper, and the stay-bolts are also of copper; but American locomotives have steel fire-boxes, and it is found that nothing but the highest quality of ductile iron will serve for the stay-bolts. For exceptional uses such as these much Swedish iron is imported, but it is rather too soft, and is apt to elongate under repeated strains. What is known as Burden iron is considered the best American iron for the purpose; but, as combining ductility with toughness, there is at the present time a regular import of "Best Yorkshire" iron to America. Rivets of high quality iron are less liable than steel to crystallise under hammering or when insufficiently heated. For these reasons iron rivets are frequently used for steel boilers. The quality of these is well shown by the illustrations of test specimens on page 185.

The material and processes here described are the same as have been used for the last fifty years; but, none the less, continued testing goes on to ascertain and prove that the desired quality is maintained. Strips cut for the purpose from plates or sample pieces of bars, turned down to a uniform diameter, are tested in tension till they break. Iron bars treated in this way will resist from 23 to 24 tons per square inch of section before breaking, and will elongate from 30 to 40 per cent. in a length of 4 inches. The ductility is shown also by the great reduction in sectional area of the test piece which occurs at the place of fracture, this reduction varying from 40 to 55 per cent. of the original area. Besides these machine tests, it is usual to try the iron by bending it cold, and again by heating it and subjecting it to severe operations by the blacksmith, such operations, for instance, as the bending, doubling back, and folding the iron cold, the enlarging of small holes by drifting without damaging the iron, and by other smithing operations which would distress and crack ordinary iron. Examples of such tests are shown on the opposite page.



RAILWAY NOTES FROM THE URAL RANGE

By L. Lodian

THE promise to give some notes on Russian railways, made just previous to the writer's departure to Siberia a few years ago, had better be, in part, at least, fulfilled now, before leaving on the next long-distance circuit, particularly as an interesting batch of photographs arrived by recent post from the Ural Mountains.

The graphic views on pages 190 and 191 of a couple of wrecks in the mid-Ural range give an idea of what a Russian spill is like, with native methods of handling it. The upset shown on page 190 was caused by a sweep into a herd of horses crossing the line, sixteen of them being killed; also both men on the engine. To frighten the owner of the animals from taking action for the loss

L. LODIAN IN THIBETAN COSTUME DURING HIS TRANS-ASIATIC JOURNEY

of his horses, the railroad authorities fined him 100 roubles.

The locomotives used on the trans-Ural roads are mostly Russian-built, hailing from the big works near St. Petersburg and Nijni-Novgorod. As the type shown in the pictures herewith will suggest, they are incapable of any speed performances, and the officials are content to let them haul their mixed loads at eighteen to twenty miles per hour. The wood supply beginning to give out, the fuel now in vogue is the crude oil from Batum, in South Russia.

The Russian standard gauge of 5 feet is the gauge of both lines crossing the Urals,—the northern route from Perm to Eketerinburg, and the central route from Yfa to Chelabinck. The stations average twenty to twenty-five versts apart—say, twelve to fifteen miles. Both roads are single track, with a passenger and freight service daily of five to six trains each way. Sand ballast prevails on all roads in this part of the globe.

The Russians are as expert at railroad "smashing" as any other nation, and their smashes are usually hopeless cases, but their facilities for rapidly clearing away wrecks do not compare favourably with western dispatch. They have few of the elaborate, always-prepared breakdown equipments current on railroads in western Europe and America. It is to the house Apcentef, of Zlatoyct, Central Urals, that credit is due for the fine photographs from which the plates on pages 190 and 191 have been made.

The huge cutting shown on the page opposite reveals the kind of work that made the trans-Ural Railway costly. The rocky mass on the right rises sheer 200 feet or more. Further on (the view looking west) is the Asia-Europa boundary monument. Imbedded in these rocks may be remarked different kinds of shells, proving that water once covered these heights.

Cipoctan is the first station in Asia at which the traveller stops when crossing

the Urals by the central route. It is most beautifully situated in the heart of the mountains.

There are, naturally, a number of sweeping curves through the Urals, but all tunnelling has been avoided. The writer did not see a single tunnel in the Urals. It is a remarkable fact that, during the trans-Siberian railway inspection, the writer did not observe a tunnel anywhere; and even after continuing the inspection right into the heart of Russia, about 2000 miles more of line had been covered before he saw the first tunnel. This was near Tyfa, not far from the illustrious Tolstoï's home; and it was while responding to a pre-arranged invitation from *le grand Russe*, that the writer came across this, the first tunnel noted, after 6000 miles of overland railway inspection.

The Russian railway engineer will sooner blow up a small mountain than make a tunnel, leaving a yawning chasm between the rocks, with two "streaks of rust" at the bottom thereof as a souvenir of his activity. Or, if he finds that, after going to the mountain, the mountain is not likely to yield to him, his instructions are to circumvent it by a long detour. Anything to avoid tunnelling! The primary aversion to tunnels in Russia is not alone their first cost, but their subsequent cost; for tunnels, like houses, always have "something the matter with them."

PHOTO BY CBIFT, CIPOCTAN, SIBERIA

THE KIND OF WORK THAT MADE THE TRANS-URAL RAILWAY EXPENSIVE. A TYPICAL CUTTING IN THE HEART OF THE URAL MOUNTAINS. THE ROCKY WALLS ON THE RIGHT RISE SHEER 200 FEET

During four months of inspection touring in the central and northern Ural ranges the writer crossed and recrossed the mountains almost a dozen times, purposely prolonging the round of visits for the purpose of recuperating after the trying trans-Asiatic inspection of the great Siberian railway from the Pacific Ocean to the Ural Mountains, which had run into 366 days, with only one halt of any moment,—at Irkutçk, Central Siberia.

It is a well-known fact that the Russians got their ideas in light, yet strong, bridge structures from America, the Russian authorities sending at heavy

A PICTURESQUE SPILL IN THE CENTRAL URAL RANGE, ON THE HEADWATERS OF THE URAL RIVER
From a photograph by Apcentef, Zlatoyct, Central Urals

A COLLISION AT A SIDING IN THE CENTRAL URALS. THE SPARK ARRESTER OF THE SECOND LOCOMOTIVE WAS A LOCAL COUNTRY BLACKSMITH'S DEVICE

From a photograph by Apcentef, Central Urals

THE BRIDGE OVER THE YFA, LOOKING WEST. SUMMER TIME. LOW WATER. NOTE THE ICE GUARDS. EAST OF THIS BRIDGE COMMENCE THE FIRST ASCENTS OVER THE URAL RANGE
From a photograph by Bonkofcki, Paefka, Yfa

expense, their engineers to the United States to copy all that was worth copying. This copying they did so faithfully that the writer did not see a single notable Russian bridge originality during 8000 miles of railway inspection across Siberia and Russia. The Yfa bridge view on page 192 is a case in point. Look at it! Except for the ice-guards, you would think it was a bridge on one of the Western American lines.

On the contrary, a fair specimen of heavy and cumbrous bridge engineering is the native iron structure over the Vistula at Warszawa, designed by the Polish engineer Kervetz, and open to traffic a dozen years or so.

The bridge over the Yfa is worth noting. Viewed in midsummer, the river does not look formidable, but you should see it during the early spring floods, with its small avalanches of block-ice pounding against the ice-guards! East of this bridge commence the first ascents over the Ural range. For the photograph the writer is indebted to the engineer Bankofcki, Paefka, Camapa-Zlatoyct Railway.

To the grazdanin A. Elagin, formerly at Yfa, but now at Orenburg, the writer is indebted for the view on this page, representing a group of railway engineers taken in early summer. It is little known that the Russian and Siberian summers are so warm that most of the officials resort to white clothing, as if in the tropics. The photograph reveals the type of resolute *à-la-guerre* engineers Russia employs to build her railways.

Bodka (Nejenati) Elagin (Koronel) L. Lodian Pycki Polakcki (Denot) Hachalnik (Chef)

A GROUP OF RUSSIAN MILITARY RAILWAY ENGINEERS. FROM A PHOTOGRAPH BY ELAGIN, YFA. THE SIBERIAN SUMMER IS SO WARM THAT MANY OFFICIALS WEAR WHITE CLOTHING AS IN THE TROPICS

With the opening, a short time ago, of the trans-Siberian Railway to Stretenck, on the head-waters of the Amur and affluents, all of this northern trans-Asiatic system that is likely to be built for the next fifty years has been concluded. From Stretenck river navigation has been decided on for continuing communication with Kabarofck, whence rail is re-continued to Vladivostok.

From Chita the trans-Siberian runs into the trans-Manchurian to Citciger,

thence to Mukden and Port-Arthur. Of course, this part of China already figures on Russian maps as Russian territory,—another realisation of one of Russia's "geographic necessities." Turkey, Persia, Afghanistan, the Pamirs, all China, Tibet, India, Korea, —even Japan,—all these are calmly argued by Russian diplomats to be their "geographic necessities;" and Russian newspapers (although all having very feeble circulations, the maximum being 5000 to 7000) receive sufficient financial inspiration to propagate these ideas.

ELECTRIC POWER FOR FACTORIES

By William S. Aldrich

THE remarks in the following pages are extracts from a paper entitled "Systems and Efficiency of Electric Transmission in Factories and Mills," read by Professor Aldrich recently before the American Society of Mechanical Engineers.

They are particularly apropos at this time when electric power development is going on so rapidly. It is worth recalling now, that some manufacturers, as Professor Aldrich stated in one of the opening paragraphs of his paper, hoped that electricity would solve all of the problems, and that at once, upon its introduction into their establishments; others decided for themselves at the beginning that it would be of little or no use. Between these extremes, however, much good work has been done.—THE EDITOR.

There are many factories and mills in which the introduction of electricity for power transmission will not pay under existing conditions. There are more establishments in which it would pay and in which an investment in electric transmission would prove to be a dividend-paying investment. No general rules can be laid down. Each case must be carefully examined, and a most thorough preliminary survey made of all the conditions and requirements.

The system of electric transmission for a manufacturing establishment is the only one which admits of economically centralising the so-called "mechanical plant" supplying light, heat, and power. It is a great advantage to be able to locate the power house near coal and water supplies. In some cases it thereby allows the use of condensing engines instead of non-condensing. By adopting electric transmission the engine may be located at any convenient distance from the machines, while shafting transmission imperatively requires that it be located as near by as possible.

If steam power is converted into electricity for all of the mechanical operations of a manufacturing establishment, it admits of a subdivision of the generating plant into duplicate and interchangeable units, the advantages of which will be apparent. The generating plant may be operated at all times in such a manner that each engine is loaded to its normal capacity. One or more units may be held in reserve for rush work and heavy orders. Night shifts can be supplied with power in units suited to their work, rather than requiring the usual single large engine to be operated as in the ordinary day shift. Nearly uniform loads may be maintained on the engines, both day and night, the electric light load, at night, offsetting additional electric motor service during the day.

In some cases it may be found necessary or desirable to have a mixed system of steam and electric distribution, but it can be obviated, with increased economy, by judicious installation. The

use of small steam engines about an establishment, for any purpose whatever, is to be deprecated. The maximum economy to-day is to be obtained by centralised power generation.

There are, of course, certain operations in manufacturing work best performed by compressed air, while others are best performed by hydraulic pressure. Electricity does not enter these special fields. Compressed air and hydraulic pressure provide means for performing work by the more or less direct application of the energy distributed by these fluids. They would not be seriously considered as suitable systems for general power transmission for such short distances as are required in factories and mills.

For all manufacturing operations (except the very lightest) requiring rotary motion, continuous or intermittent, uniform or variable, and reversible or otherwise, electric motors provide the readiest facilities. For certain very definite reciprocating movements, with fixed time or distance limits, hydraulic mechanisms are best suited, though electric-motor-driven hydraulic mechanisms with hydraulic control have proven admirably adapted to this class of work. For reciprocating movements requiring a cushioning effect, compressed air is best adapted. But for efficient service in any case compressed air requires to be reheated and used expansively in a cylinder with all parts and mechanisms practically the same as in the steam engine. Electric transmission is equally adapted for all of the so-called auxiliary machinery of a manufacturing establishment, the non-productive machinery, pumps, compressors, fans, blowers, cranes, hoists, lifts, etc.

In choosing a system of electric transmission for manufacturing work it is not necessarily best to have that one system which will the most readily lend itself to all of the work to be performed, for light, heat, and power service. A composite system may prove best suited, even in such short-distance transmission; that is, lighting service will, in general, be more satisfactory, and need not be more expensive, if supplied independently of the power service. Direct and alternating currents are equally adapted for factory transmission, and by simple or multi-circuit systems of distribution; that is, by two, three, or four-wire systems, as the case may require. Preferably, all distribution should be direct,—without the use of storage batteries, rotary converters, or transformers, except for certain lines of work in which it may be necessary to use one or the other of these indirect systems of distribution.

In the matter of voltages a wide range is possible:—110-volt two-wire and 220-volt three-wire systems for use of either direct or alternating currents for light and power; 440-volt two-phase alternating-current three or four-wire systems for both light and power; 550-volt direct-current two-wire systems, or 550-volt alternating-current three-phase three-wire system, chiefly for power service, or the monocycle system for both light and power. In general, it will not be necessary nor advisable to use over 550 volts, direct or alternating current. Shocks arising from accidental contact with wires carrying currents of this voltage are not necessarily dangerous. Experience has shown that the higher the voltage, the more workmen respect the distributing wires. But it is not necessary to command such respect by raising the voltage above 550.

At the time that electricity was introduced into manufacturing establishments the direct-current system was the only one available. For the peculiar and exacting service required in driving all kinds of machine tools and various workshop appliances, there were difficulties to be overcome with any system. It was necessary to secure satisfactory methods of producing a large starting turning moment, or torque, for varying the speeds as might be required under uniform or variable loads, and for reducing to a minimum the trouble arising from the use of a commutator.

The difficulties with commutators have been almost entirely overcome, and many refinements in design effected so that the direct-current motor of to-day leaves little to be desired. Such

objectionable features as still remain are inherent in the direct-current system used, and are found to lie chiefly in the kind of armature, commutator, and brush devices required. These parts are most liable to derangement, require systematic attention for cleanliness and efficiency and renewals of brushes.

In heavy work, with the ordinary rough usage which an electric motor receives in a factory, a commutator may in less than an hour become so dirty as to result in considerable heating, due to increased mechanical friction of the carbon brushes, and to the increased current required by their imperfect contact. Dust-proof casings remove several of these possibilities to a more remote time. But, somehow, workmen expect an electric motor to take care of itself; at least they treat it on this assumption. If a motor were sure of the daily care and inspection formerly bestowed upon shafting and belting, it would have made a much better record earlier in its history. Electric motors cannot usually be similarly inspected and attended to while at work, as in the case of the older system of mechanical transmission. To have such work performed at any time requires a skilled attendant.

The alternating current system, with its induction motor service, offered practically the only alternative to those engineers and manufacturers who did not care to be troubled with the petty annoyances and delays likely to occur at any time with the direct-current motor. The induction machine as it stands today is probably the most perfect motor yet developed from the standpoint of electric transmission in factories and mills. It may be started and operated from any point, at any time, at practically any load and speed within its predetermined ranges. It may be used on 110, 220, 440, or 550-volt alternating-current circuits of one, two or three phases. It does not require any direct current supply as the synchronous motor does for its field excitation. It does not require any brushes, commutator or collecting rings. Offsetting these advantages, however, are certain restrictions. The speed of an induction motor falls off slightly as the load is increased. The ability to start an induction motor from rest under a heavy load, as well as the possible speed changes during its operation, are obtained at some sacrifice of efficiency.

Induction motors, moreover, permit of higher lineal speeds than are possible with any other type, from 6000 to 7000 feet not being infrequent. By suitable arrangements of its field windings this type of motor may have its speed altered in regular steps, so reducing it one-half, one-quarter, one-eighth, etc. This makes possible similar changes to gear-wheel combinations, which may, therefore, be eliminated to the extent that the induction motor is installed to effect such changes. In almost all cases of shop driving the slip is not objectionable, any more than the increasing slip of the driving belt as the load is thrown on. These motors will stand almost any amount of rough usage and heavy overloads, as they cannot be burned out. If excessively overloaded, the motor slows down and stops, starting up immediately as soon as the load is lightened. Ordinarily, machine tools and almost all classes of shop machinery are started at quite light loads, and the full load is thrown on when the work or the tool is up to the speed desired. For this class of work the induction motor seems specially fitted.

A larger generating power plant is required for an installation of induction motors than would be the case if direct-current motors were used. This is on account of the energy which is lost in all classes of alternating current circuits in which there is considerable self-induction, whether in the transmission wires or in the appliances used. In the case of induction motors this loss is very appreciable at light loads, becoming much reduced at average and heavy loads, at which it is almost uniform.

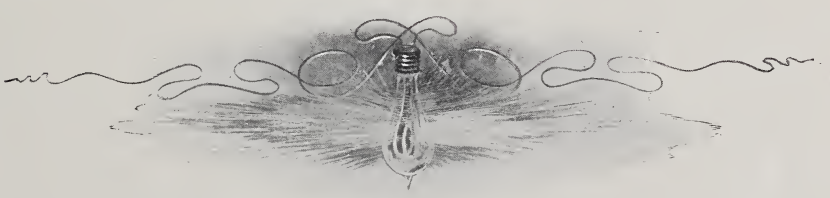
Synchronous motors are admirably adapted to factory service where absolute uniformity of speed is required, and where the extra installation of a direct current supply for their field excitation is not deemed objectionable. While induction motors are always wasteful of

some energy, through their high self-induction, synchronous motors may, on the other hand, be brought into that condition of operation practically equivalent to the use of direct-current motors, at least for a large range of their loads. In other words, the power factor of a synchronous motor may be made almost anything from zero to unity, according to the extent of excitation of its fields by the direct current applied for this purpose.

When made in the revolving field type, synchronous motors are self-starting from rest, at light loads. They may be very heavily overloaded, without falling out of synchronism or out of step, and when they do for an instant, they may be brought back again by throwing off some of the load. A well-designed synchronous motor will carry at least three times its full normal load and not drop out of step. If an induction motor is built for such overloads it is likely to have quite low efficiency at ordinary loads.

The ideal conditions in a factory installation no doubt would be secured where both induction and synchronous motors were used, the former for small machines and direct driving, the latter for operating a set or group of machines. The synchronous motors would be started up just before beginning the work of the day, have at all times a light, constant load, and might easily be so regulated as to produce an almost balanced system in combination with the induction motors. In such a system of transmission the lagging currents of the induction motors would be offset by the leading currents of the synchronous motors, if the latter were operated to produce such leading currents. The whole system would be operated practically throughout quite a range of load variations, as if it were a simple direct-current system. The advantage of such a condition is apparent: it means least installation for any given output, or greatest output for any given capacity of generating plant. The group method of electric driving is much better adapted for small machines, up to and including 2 horse-power capacity, and especially where such machines are in almost constant service. Above this size individual motor driving becomes more and more efficient, particularly if the machines are operated only a fraction of the day.

It might naturally be expected that the greatest saving would be noticed in those factories engaged in heavy machine work, where the loss in shafting and belting amounts to over 50 per cent. of the total power developed at the engine. On the other hand, many small industries have introduced electric driving to marked advantage.



INVENTION AS A FACTOR OF AMERICAN NATIONAL WEALTH

BENEFITS OF THE UNITED STATES PATENT SYSTEM

By W. C. Dodge

MUCH has been said and written of late in regard to the increase of America's foreign trade, and expansion has been urged mainly on the ground that it will furnish new markets and increase foreign trade. It is not the writer's object to discuss that question, but instead to show briefly what it is that has increased America's productive capacity, the part that the patent system of the country and its resulting inventions have had in that increase, and that in future dependence must, more than ever, be placed upon inventions for ability to compete for the trade of the world.

To do justice to this subject would require far more space than can be given in an ordinary magazine article, for the history of inventions and the part they have played in the prosperity and growth of the United States would be to write the history of the country. Indeed, the history of invention is the history of civilisation, for together they have marched down the ages, and will so continue to do while time lasts or man exists.

The writer knows of no better way to illustrate the beneficial effects of the patent system in the United States than by a brief review of the growth and prosperity of the country, and the part that patented inventions have had in that growth and prosperity. Going back but a little over a century, we find the United States consisting of the original thirteen States, with a population of less than 4,000,000 people, living in sparse settlements scattered along the Atlantic seaboard, the most western of which scarcely reached half way to the Mississippi River. Moreover, it must be borne in mind that this small number of settlers had the whole continent to subdue, the forests to clear, farms to open, houses, roads, bridges, schools, churches to build,—in fact, everything to create from the ground up, with the savages to contest every foot of advance; and that they had neither the accumulated capital nor the surplus labour of the Old World with which to accomplish this gigantic task.

Their condition was well described by Senator Thomas C. Platt at the United States Patent Centennial, when he said that "manufactures were practically unknown; that there were no mechanics, as we now understand the term; that men knew how to plough and sow, hoe and chop, reap, mow and cradle, break flax and hackle it, thresh with the flail, winnow with the blanket or fan, and to shell corn by hand. The women knew how to spin, card, weave, and knit. Mechanical knowledge was monopolised by the blacksmith, the carpenter, the millwright, and the village tinker. Production was a toilsome, weary task, limited by the capacity for muscular endurance."

It should also be remembered that such things as steamboats, railways, electric power and light, reapers, mowers, cultivators, threshing machines, and the thousand and one appliances which, of late years, have contributed so much to prosperity, were then unknown; and that when Fulton built his steamboat the engine had to be brought from England, there being no means for making it in the United States.

But that was not all, for, in order to get a clear idea of the conditions under which the United States began their ex-

istence as a nation, one must also consider the restrictions placed upon the colonists by the mother country. Her policy was well expressed by Sir William Pitt, who said: —

"It is the destiny of America to feed Great Britain, and the destiny of Great Britain to clothe America."

In other words, America was to remain for all time an agricultural country, furnishing the people of Great Britain with food and the raw material for her manufacturers, while she was to do the manufacturing. Her policy as to manufactures in the colonies was well expressed by Lord Chatham, who said: —"I would not allow the colonists to make so much as a hob nail for themselves."

In accordance with this policy, Great Britain enacted laws prohibiting every species of manufactures in the colonies. Even a hat factory in Massachusetts was declared a nuisance, and its existence ordered abated. When the colonists began to make iron and nails for their own use, the House of Commons resolved that "none in the plantations should manufacture iron wares of any kind out of any sows, pigs, or bars whatsoever," and the House of Lords added that "no forge going by water, or other works, should be erected in any of the plantations for the making, working or converting of any sows, pigs or cast iron into bar or rod iron." A bill was also introduced in Parliament which prohibited the erection of any mill for slitting or rolling iron, for the manufacture of spikes or nails, or any plating forge to work with a tilt hammer, or any furnace for making steel, and also proposed to abolish the few which had been built; and by the act of 1750 the further erection of all such was prohibited.

It was the same with the textile industries. Not only were the colonies prohibited from transporting any manufactured articles abroad, but also from one colony to another; and to still further cripple the growth of manufactures, an Act of Parliament forbade, under severe penalties, even to outlawry, the departure from Great Britain of any artificer in any of the various branches, and also the exportation from Great Britain of "any machine, engine, tool, press, paper, utensil or implement, or any part thereof, which then was, or thereafter might be, used in the cotton, woollen, or silk manufacture, or any model or plan thereof," under a penalty of forfeiture, a fine of £200, and a year's imprisonment, and the like penalty for any one "having, collecting, making, applying for, or causing to be made any such machinery;" and when, in 1684, the colony of Virginia passed an act to encourage the manufacture of textile fabrics, the act was annulled by Parliament.

When coal was discovered and began to be used, an Act of Parliament prohibited any collier or miner from leaving the kingdom under similar penalties. As was said by Burke:—"This principle of commercial monopoly runs through no less than twenty-nine Acts of Parliament, from 1660 to the unfortunate period of 1764."

Nor was this policy confined to manufactures alone, for as early as 1622 the exportation of tobacco from Virginia was prohibited, unless first landed in Great Britain, and a duty paid there. These laws were enforced long after American independence. As late as 1830, Hugh Wagstaff was imprisoned for putting on board the American vessel *Mount Vernon*, for New York, twenty-three boxes of spindles to establish a cotton factory in the United States, and the spindles were confiscated. And when the Hon. Tench Coxe, the coadjutor of Alexander Hamilton, entered into a bond with a party in London to send hither models of Arkwright's patented spinning frame, they were detected and confiscated.

As late as 1832 the model of a roller for printing calico, to be used at Lowell, was obtained only by concealing it in a lady's trunk; and, still later, when Messrs. Sharp and Roberts, of Manchester, England, who in 1841 patented their self-acting spinning mule in the United States, sought to send the patterns to their partner, Bradford Durfee, at Fall River, Mass., they suc-

ceeded only by smuggling them through France. The laws prohibiting the emigration of artificers were not repealed until 1825, and that prohibiting the exportation of machinery, etc., not until 1845.

Under these conditions the colonists could do nothing but produce food and raw materials for the manufacturers of Great Britain, and even those had to be shipped in British vessels, of which the officers and three-fourths of the crew must be British subjects.

During the American Revolution manufactures were established to partially supply American needs; but as under the confederation, which was simply for mutual defence, Congress had no power to regulate commerce or impose duties on imports, and as those colonies which were interested in commerce favoured free trade, the country was soon flooded with cheap foreign goods to such an extent as to destroy what manufactures there were, and bankrupt the merchants who had stocks on hand. The country was drained of its money, and the condition became such that laws were passed suspending the collection of debts, and making cattle and other kinds of property a legal tender. Petitions were sent to Congress asking it to issue "fiat" paper money and loan it to the people, and Pennsylvania actually did this.

It was this condition of affairs that finally resulted in the Constitutional Convention of 1787, which conferred on Congress the powers under which the United States have since grown to their present estate. Among those powers the two most important, so far as national prosperity is concerned, are, the power to regulate commerce and impose duties on imports, for the twofold purpose of raising revenue and protecting the then "infant industries," and the power to "promote the progress of science and useful arts" by the grant of patents.

Under the exercise of those powers America has grown and prospered as no other nation on earth has. What that growth has been may be epitomised by saying that from that little beginning in 1790, the United States have grown until to-day they do one-third of the world's manufacturing, one-third of its mining, one-fifth of its farming, and possess one-fifth of its wealth.

Years ago, Gladstone, in his book entitled "Kin Beyond the Sea," said:—"America will probably become what we are now,—the head servant in the great household of the world, because her service will be most and the ablest."

Already America has reached that point, for as Mulhall, the British statistician, recently said:—"If we take a survey of mankind in ancient or modern times, as regards the physical, mechanical, and intellectual force of nations, we find nothing to compare with the United States in 1895. The physical and mechanical power which has enabled a community of wood-cutters and farmers to become, in less than 100 years, the greatest nation in the world, is the aggregate of the strong arms of men and women, aided by horse-power, machinery, and steam-power, applied to the useful arts and sciences of every-day life."

And he adds:—"The intellectual power of the Great Republic is in harmony with the industrial and mechanical. The census of 1890 showed that over 87 per cent. of the total population over ten years of age could read and write. It may be fearlessly asserted that, in the history of the human race, no nation ever before possessed 41,000,000 instructed citizens."

He also shows that the wealth of the United States is $23,000,000,000 (£4,600,000,000) more than that of Great Britain, seven times greater than that of Spain, nearly double that of France, and equal to the combined wealth of Russia, Italy, Austria and Spain; and that America's productive capacity is not only greater than that of any other nation, but that, from 1860 to 1895, it has increased far more rapidly than that of any other, the increase per capita being at least 30 cents per day. In 1793 the gross receipts of the United States were but six and two-thirds million dollars, a little over $20,000, or about £4000 per day. In 1898 they were

over seven hundred fifty-eight and one-half millions, or nearly two and one-half million dollars, or about £500,000, per day.

In 1796 such was the credit of the United States that when the Commissioners, under authority of Congress, borrowed $200,000 to complete the public buildings, the State of Maryland, in loaning them that amount in United States stocks held by that State, required the Commissioners to give their personal obligations as additional security; and on that $200,000 of United States stocks they could realise but a trifle over 65 per cent! Within a few years past the government has paid 130 per cent. for its own bonds in order to redeem them in advance of their maturity,—a thing that no other nation has ever done. And only recently, when an offer was made to sell $200,000,000 of 3 per cent. bonds, they were subscribed for seven times over by the people, and in less than six months they commanded 7 per cent. premium in the market. And now under the recent act to fund the national debt by the issue of 2 per cent. bonds, $260,000,000 of them have been taken in three months. No other nation has bonds bearing so low a rate, the lowest being a portion of British consols bearing 2½ per cent., while the latest for the war in South Africa bear 2¾ per cent. The debt of European nations ranges from $75 to $115 per capita, while that of the United States, which was $52.96 in 1872, was but $13.81 in 1898, and it has decreased ten and one-fourth million dollars in 1899.

When the writer was born there was not a mile of railway in the United States. To-day there are 186,000 miles in daily use, with a total of nearly 250,000 miles of track,—as much as all the rest of the world. A locomotive running 30 miles an hour, 24 hours a day, without a single stop, would consume almost an entire year to traverse the whole extent. One of these roads alone carries more tonnage annually than all the merchant vessels of Great Britain; and, according to Mulhall, the amount of merchandise carried by the railways of the United States is double that of all other railways collectively. And, as has been said, "the railroad, from the steel rail to the top of its smokestack, from its headlight to the signal light on the platform of the last car, is but one aggregation of patented inventions."

The internal and coastwise commerce of the United States by water and rail amounts to more than the foreign commerce of Great Britain, France, Russia, and Belgium combined. Every year there are over 60,000 passages of vessels through the Detroit River, carrying over 40,000,000 tons of freight, and over 80,000 passengers, or nearly fifteen times as many as through the Suez Canal. In 1899 nearly 19,000 vessels arrived and cleared at Chicago,—very nearly as many as at London, which leads the world.

The American people write 40 per cent. of all the letters in the world, and the American postal service is the greatest in the world, the travel on all the routes being enough to reach 17,000 times around the globe each year; and there are more miles of telegraph and telephone wires than in all other countries.

The annual gain in wealth is about $2,000,000,000; and last year the earnings amounted to $14,500,000,000, one-half of which was paid to labour. Each working day adds $6,000,000 to the nation's wealth. The capital has been multiplied more than threefold since 1870, and at that rate there will be added in the next ten years as much as the entire capital was in 1870.

These facts are mentioned not by way of boasting, but as showing the marvellous growth of the country during its first century. Now what has done all this? What force, what power has been at work? In the words of Senator Platt, the writer answers, "it is the spirit of invention, the creative faculty in our people, that hath wrought these wonders." It is the result of American inventions fostered by the American patent system, — the best in the world.

As illustrating the part that patented inventions have had in the growth and

prosperity of the country, let me mention a few! Take the cotton-gin, invented in 1793! When eight bales of cotton were first sent from Georgia to Liverpool, in 1784, they were seized by the customs officers, who did not believe it possible that so much cotton could be grown in America. At the present time the American cotton crop amounts to 11,000,000 bales. To remove the seed from that amount of cotton by hand would require the labour of 18,000,000 persons, working every week-day for the entire year. And to card, spin, and weave it by hand would require more than the entire population of the country; and yet, by the aid of inventions, America manufactures annually about one-fourth of the world's consumption.

Never was there a truer sentence written than that of the biographer of Whitney, the inventor of the cotton-gin, when he said:—"This inventor created both personal and national wealth." As Mr. Justice Johnson, of South Carolina, said, Whitney's invention had trebled the value of the lands in the South; and it was shown by statistics that the pecuniary benefit to the country during the first forty-three years was $1,400,000,000, and during the sixty-two years since it has amounted to many times that. As was well said by Mr. Lanman, "Whitney's invention had given an impulse to the agriculture of the South which has remained unimpaired to this day, and which would endure while the cotton plant whitens the plantations with its snowy blossoms, or the machinery of the cotton mill continues its clatter at the waterfalls."

And though the South was slow to avail itself of the benefits to be derived from the manufacture of the cotton there, she has now taken hold of it with a will, for she already has 450 cotton mills, with about 5,000,000 spindles, in operation, her investment in that branch having grown from $21,000,000 in 1880, to $125,000,000 in 1899. And it is a singular fact that South Carolina, which, in 1828, threatened nullification because of the tariff designed to build up American manufactures, now ranks next to Massachusetts in the number of her cotton mills.

The establishment of these cotton mills has given remunerative employment to labour, prosperity to the merchants, a permanent, steady market to the farmers and truck gardeners, supplied towns with more and better schools and churches, while the country for miles around is in a much more prosperous condition, and the value of the lands has largely increased. But for the cotton-gin, this could not have occurred.

In like manner the report of the United States Agricultural Department for 1884 shows that, taking the country as a whole, the establishment of manufactures in any locality doubled the value of the lands in that region. The report states:—

"Miners, mechanics, and especially artisans and operatives engaged in productive occupations, are vastly more beneficial to agriculture, for two reasons:—First, they augment the numbers to be fed and increase agricultural values; second, they make something themselves which farmers need, and reduce the prices of commodities hitherto brought from a distance at unnecessary cost."

As another illustration, take the common nail! In 1818, when nail making began with a machine operated by hand, nails cost from 18 to 37½ cents a pound, according to size. By improvements in nail machines, nails are now sold so cheap that a carpenter, working for forty cents an hour, had better let a nail go than to spend the time to pick it up, for his time is worth more than the nail.

Again, take the case of iron and steel! In 1866 steel rails cost $165 per ton. By the improvements since made they were reduced to $21, in 1893, though higher now, because of the scarcity and great demand abroad as well as at home.

In 1870 Great Britain produced nearly 59 per cent. of the world's supply of pig iron, and the United States but 15 per cent. Since 1870 Great Britain's product has increased but 29 per cent.,

while that of the United States has increased 460 per cent., the American output for 1899 being about 14,000,000 tons of pig iron, and nearly 9,000,000 tons of steel. To-day the United States is the iron master of the world, and that fact is mainly due to American inventions; for, as the superintendent of one of the large steel works recently stated, by the adoption of the latest inventions they were able to produce a ton of steel with one-third of the manual labour that was required at another works built twenty years before.

Mulhall says:—" It may safely be asserted that the world has never before seen such a development of hardware industry as in the United States in the past five years," and that, notwithstanding several years of depression.

In 1824 a member on the floor of Congress contended that America could never compete with Europe in the production of iron, because of the cheaper European labour. Little he knew the power of invention, backed by American enterprise and energy; for, by its aid, America last year not only supplied her own needs, but sent pig iron, rails, locomotives, bridges, machinery, and tools of all kinds, not only to Europe, but to Asia and Africa, to the amount of over $105,000,000; and, while doing that, paid her operatives nearly double the wages paid in Europe. Only recently a vessel left Philadelphia, for a European port, carrying a cargo worth nearly half a million dollars, in which were thirty locomotives and tenders, with other machinery and tools.

Again, take the tin-plate industry! Up to 1890 America produced but one per cent. of the tin-plate that she used. In 1891 there were imported nearly thirty-six million dollars' worth, but in eight years that industry has so grown that the import is reduced to less than $4,000,000, and that is mainly used for the shipment abroad of oil and other canned goods, and on which tin a drawback is allowed. Not only does America now supply herself, but the export of tin-plate has commenced, and during the past year it grew from 78,500 to 280,591 pounds. That is not much, it is true, but at that rate of increase it will soon amount to a large sum.

While it is, no doubt, true, as claimed, that the establishment of the industry was due to the protection afforded by the tariff of 1890, its unexampled growth and prosperity are largely due to invention. It has been claimed that there have been more improvements in the manufacture of tin-plate in the United States in eight years than there have been in Wales in two hundred years; and these improvements consist mainly in the use of labour-saving machines and tools patented by American inventors.

The same is true of every branch of manufacture. The records show that the growth of manufactures and patented inventions has increased in parallel lines. In 1830 American manufactured products amounted to only $80,000,000, and up to 1836 less than 10,000 patents had been issued.

In the twenty years from 1830 to 1850 the manufactured products had grown to $1,015,000,000; and from 1836 to 1850 45,333 patents were issued. In every decade since then, American manufactures have nearly doubled, until in 1890 they represented about nine and one-fourth billions of dollars, and the patents issued had reached 418,665, from 1836 to 1850.

A very remarkable fact in connection with this is that while the hours of labour have been reduced 25 per cent., the product per hand has increased 40 per cent., and the wages 48 per cent.; or, if measured by the purchasing power of a dollar, 68 per cent. The world has never before witnessed such results anywhere.

Now what is it that enables an operative in three-fourths of the time to produce nearly double what he did forty years ago? It is simply invention,—the inventions embodied in improved machines, tools, and processes. Ten years ago the American import of manufactures was double the export; to day the export is double the import.

During the year 1899 the export of manufactures amounted to $380,787,891. The total of exports for 1899 amounted to $1,275,499,671, which ex-

ceeded the imports by about $600,000,000; and, according to the report of the statistical bureau, American exports during the month of February, 1900, averaged $5,000,000 for every business day, or more than 25 per cent. more than for any preceding February, the exports during the month exceeding the imports by $50,991,612, and that, too, notwithstanding the imports exceeded those of any previous February. The total of exports for the month amounted to $119,765,762, while the imports were but $58,774,150. It is estimated that, at this rate of increase, American exports for the fiscal year ending June 30, 1900, will exceed those of 1899 by $100,000,000, and that the total commerce of the year will exceed $2,000,000,000. The export of manufactures for the year ending June 30, 1900, will exceed $400,000,000.

That the wonderful increase in American manufactures is mainly due to inventions encouraged by the patent system, cannot be doubted by any one who will examine the subject. Commissioner Leggett, in his report for 1873, said that from three-fourths to nine-tenths of all American manufacturing is based on patents,—that is to say, patented articles are manufactured, or patented machines and processes are used to manufacture articles that are not patented.

The *Iron Age* has said:—"It should not be forgotten by those who sneer at inventors that out of the $8,000,000,000 invested in manufacturing in the United States, patents form the basis for the investment of about $6,000,000,000, or three-fourths of the whole." And it adds:—"The one thing that has enabled our manufactures to make so wonderful a progress has been our patent system."

On this point the United States Commissioner of Patents, in his report for 1898, says:—

"At the present time, when our manufacturers are reaching out for foreign markets, I believe no greater aid can be given them than by fostering and stimulating invention. The United States can only become dominant in the markets of the world through labour-saving inventions which will enable it to compete with the lower wages paid to the so-called working classes in other countries. The greatest development in American exports must be in the direction of increase in the export of manufactures. I assert, without fear of successful contradiction, that we mainly owe to our patent system such foothold as we have gained during the past fifty years in foreign lands for our manufactured products. * * * *

"Let us not forget that it is the American inventors who, by their inventions and discoveries, 'have made the last fifty years of the nineteenth century the most remarkable of recorded time,' and, at the same time, have laid the civilised world under tribute to American manufactures."

It must, however, be apparent to every observing person that protection in the form of a tariff is constantly becoming of less importance to the United States. Now and then, in the establishment of a new industry, as was the case in the manufacture of tin-plate, it may be of great importance; but such instances can occur but seldom in the future, for nearly all branches of manufactures are now well established in the United States. When America can manufacture as cheaply as others, and can compete with them in the markets of the world, it is obvious that such branches do not longer require protection. In all such branches importation will cease, or nearly so, as is the case to-day with iron and steel, machinery, tools, etc., and the revenues from that source will, therefore, constantly decrease, so that in the course of time America, like Great Britain, will practically adopt free trade, except as to such articles as, from the nature of the case, cannot be manufactured economically in the country, and internal taxation of one kind or another will have to be depended upon more and more for national revenue. This will be the natural and inevitable result of the tremendous strides America is now making in manufactures.

Just in proportion as the country ap-

proaches that condition, just in that proportion will the importance of the patent system increase. Already it has become the main reliance in the growth and increase of manufactures. But the benefits of the patent system have not, as many suppose, been confined to manufactures. The system has done as much for agriculture. The American corn crop amounts to over 2,000,000,000 bushels per annum. Were it not for corn planting and cultivating machinery what would the corn crop amount to,—and, without the corn, where would be the pork and beef, either for use or export, and of which America exported 193,500,000 dollars' worth in 1899? The wheat crop in 1898 amounted to 675,000 000 bushels, and since 1870 the export has averaged over 120,000,000 bushels per annum. Suppose we were to strike out of existence the dozen or more leading inventions used in the preparation of the soil, the seeding, harvesting, threshing, storing and transporting of the crop, what then? Not a bushel could be exported, because, by hand, it could not be produced; and even if produced, it would cost so much that it could not be delivered in Europe cheaply enough, and Europe would, therefore, not buy it.

During the World's Fair at Chicago in 1893, a delegation of European officials visited the wheat fields of Dakota, and were astounded to find there one hundred and forty automatic harvesters and binders at work on one farm, while at the same time the steam threshers, using straw as fuel, were threshing, cleaning, and sacking 1500 bushels per day. At a dinner given them, it was said that by the adoption of improved implements the cost of raising wheat had been reduced to $4.50 or $5 per acre, and that of harvesting to half a cent a bushel.

In the words of Senator Vance, "American labour-saving inventions form an epoch in the history of the race;" and, as another has said, "Americans use implements that cheapen the cost of production, and make the labour of harvesting seem like the sport of the fairies in the story-book. As with manufacturing, so with farming,—inventions have so reduced the cost of production that there is more propriety in saying that we manufacture wheat than in saying that we raise it."

Indeed, there is scarcely a thing done on a farm to-day in which patented machinery does not perform the greater part of the labour. The grain is sowed, cut, bound, threshed, cleaned, sacked, stored, and transported by machinery, the corn is planted, cultivated, and cut by machinery, while the mower cuts, the tedder spreads, the horserake gathers, the hayloader loads, and the carrier unloads the hay. The potatoes are planted and dug by patented machines or implements, and even the hogs are slaughtered and the chickens hatched by machinery.

In the household we have the sewing machine, the washing machine and wringer, the egg-beater, the nutmeg grater, the meat grinder, the potato shredder, and countless other implements, all the result of the patent system. In fact, one cannot touch a thing in the factory, on the farm, in the office, or the household, that does not bear the impress of patented invention. Without the patent system these inventions would probably not have existed.

To-day all Europe is alarmed at American progress in that line, and her public men and press everywhere agree that America's wonderful growth is due to her patent system. After the Centennial Exhibition at Philadelphia, in 1876, Lord Kelvin, then Sir William Thomson, said:—"I was much struck with the prevalence of inventions,—it seemed that every good thing was patented. If Europe does not amend her patent laws America will speedily become the nursery of inventions for the world."

Mr. Hulse, one of the British judges, said that the extent of ingenuity and invention exhibited was extraordinary. So, too, the Swiss commissioners told their people that their only hope was the adoption of the American patent system.

Dr. Grothe, a German who came to study American industries, said that American labour-saving machinery and tools had so reduced the cost of manu-

facture that already in many lines Americans could compete successfully with both British and German manufacturers, that this was mainly due to American inventions, and that, judged by its results, the American patent system must be admitted to be the most successful.

A European expert who recently visited the United States to study American industries, said that in Massachusetts, where the operatives in a shoe factory are paid $15 per week, the cost of labour on a pair of shoes was 40 cents, while in Germany, where the wages were but $3.80 per week, the cost was 60 cents, and that this was due to American inventions. Pages could be filled with similar testimony from competitors of the Old World.

One of the best results of the extensive use of inventions is, that while nearly everything has been greatly cheapened, the purchasing power of a day's wages has been increased 72 per cent, and, as shown by a report of the United States Labour Bureau, the introduction of labour-saving machinery, instead of displacing labour, has increased the number employed in a much greater ratio than the increase of population. Since 1865 the productive capacity of skilled labourers has been increased three-fold, and that is mainly due to the adoption of labour-saving machinery invented by Americans.

According to a recent statement of the Commissioner of Labour, in 1890, by the use of labour-saving machinery operated by 6,000,000 horse-power, less than four and one-half millions of operatives produced of manufactured articles an amount that would have required 36,000,000 operatives using the old hand methods. Thirty-six million operatives represent a population of 180,000,000, —two and a half times as many people as there are in the United States.

Commenting on this, the commissioner says the statement seems fantastical, and is difficult to comprehend. The truth even smacks of fairy tales, or the statements of a statistical Munchausen, and yet it is based upon figures produced by a thorough examination conducted by the Bureau of Labour under authority of Congress.

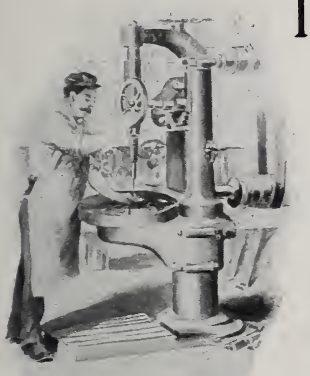
All great writers agree that invention is not only one of the noblest avocations, but that it is one of the greatest factors in the increase of national wealth. The founders of the United States government builded better than they knew when they placed in the Constitution that little clause authorising Congress to promote the progress of science and the useful arts by the grant of patents, for then and there they laid the foundation for the material prosperity of the country. And while giving full credit to statesmen and soldier heroes, it may safely be asserted that no class of citizens has done more for the prosperity and glory of the United States than its inventors.

The patent office is the only self-sustaining bureau the government has or ever had. Besides paying a large portion of the cost of the erection of the patent office building, it has defrayed its own expenses since the enactment of the law of 1836 which required it to be self-sustaining, and to-day has a surplus in the United States Treasury of over $5,000,000, every dollar of which has been paid by the inventors and those interested in patents, and who, in addition, have paid their full share of the expenses of the government the same as all other citizens.

MACHINE TOOLS IN THE MECHANIC ARTS

By Dr. Coleman Sellers

From an Address delivered before the Franklin Institute, with additions as to modern methods.



THE greatest advance in mechanics has been manifested since the advent of the locomotive. It so happens that the birth of the modern railroad system is coincident with the writer's own birth. At that time the first railroad was put into operation in Great Britain, which development, taken in connection with the advent of the steamboat which preceded it, was certainly an exciting cause of the great industrial advance that has since been made. Previous to 1827 wooden rails had been laid to form roads over which ore was hauled from the mines, and coal was transported in the same manner by animal traction to better advantage than over common roads. The idea of the high-pressure steam-engine had been conceived, and, with the full understanding of its value, a practical traction engine for common roads, was one of the first examples of its application. It was after the invention of the road engine that the locomotive upon rails became possible.

The traction engine applied to the railway was the basis of the present wonderful systems of inland intercommunication, and its development has given an impetus to all trades. In fact, the wants of the railway, taken alone, would have been sufficient incentive for what has since been done in the mechanic arts, engaging, as it has, the attention of engineers to produce the labour-saving tools required for the improvement and preservation of the railways and equipment, including the great iron and steel works that supply the rails, bridges and buildings.

Referring to this more particularly in an address delivered before the Franklin Institute last year, dealing with the progress of the mechanical arts during the last three-quarters of this century, the writer pointed out that special machinery has been constantly needed to render possible such industries as iron and steel shipbuilding, bridge and structural work, and the appliances which have been introduced in place of hand labour throughout the industrial world. The progress of the single industry of machine tool building has, therefore, a most important bearing on this subject, and traced through the many stages of its rapid growth, the development of this one industry would be sufficient to illustrate the progress in mechanic arts during the period in question.

The important relation which tools and implements bear to the mechanic arts, and, in fact, to all arts and crafts, forms the subject of an interesting tradition depicted in a painting by Schusselle representing a blacksmith seated at the right hand of King Solomon's throne in his great temple, to illustrate an event during the feast given in Jerusalem at the completion of the edifice. To this feast had been bidden the various artisans who had been engaged upon the construction and decoration of the building, those who had helped to shape the gold and silver and carve the ivory and weave the costly hangings that decorated its walls. There also came, unbidden and unrecognised,

the swarthy smith, who, forcing his way through the courtiers and the guard to the throne of the king, claimed recognition as the one man to whom was due the creation of the entire work, for it was he who had forged the tools without which the other artisans could have done nothing. The wise king, recognising the justice of the claim, gave to the smith the seat of honour.

Antedating the smith of King Solomon's day and the mechanics of all times, the progress of civilisation can be traced by the study of the implements used in the daily life of different races of man, and prominent in the progress of the mechanic arts must be counted the tools with which work has been accomplished.

As one instance of progress from primitive methods during the period under consideration, it may be of interest to refer to the construction of one of the first large engines that were built for the city water works in Philadelphia. The boring bar used in boring out the cylinder was of the crudest character, operated by hand by means of levers attached to it, so that men, walking around the cylinder, could propel the cutting tools, and gradually force the cutters on the boring bar through the cylinder, until it had been turned out approximately true. After that the inner surface had to be filed to a sufficient degree of smoothness. Probably a month was consumed in this operation of boring the cylinder. The subsequent improvements in machine tools have changed the process of cylinder boring from an effort of days to the work of a few hours.

Early in the fifties the writer entered the locomotive works of Niles & Co., of Cincinnati, as foreman, and in 1857 accepted service as chief engineer for William Sellers & Co., of Philadelphia, then, as now, engaged in building machine tools. Thirty years' active experience in machine tool building enables him to speak from a full knowledge of this industry and what machine tools have done for the advance of the mechanic arts. When engaged in locomotive building in Cincinnati, the writer introduced a number of improved methods, but was hampered continually for the want of machine tools powerful enough to do the work as he desired it done, as well as for the want of special tools not then available. At that time in the Eastern cities of the United States certain machine tools were being built with success, and were doing far better work than it was then possible with tools built in a branch of the locomotive works where the writer was engaged. The firm of Niles & Co. had, however, some reputation even then as builders of machine tools and sugar machinery, but it was not until the retirement of the original founders of the house that the works became devoted wholly to the machine tool business. At the time mentioned, slotters, horizontal boring machines and lathes of various kinds and quality were built in America after the introduction of the planing machine, the first one of which was probably introduced into the city of Philadelphia some time about 1830.

The early machine tools were of the crudest workmanship, and most of the lathes were made partly of wood. In fact, the transition from wood to iron in the construction of machinery was in progress during the early part of this century, and the formation of the tools themselves and much of the machinery built at that time involved the conversion of structural shapes required for wooden machines into similar shapes in metal. In the first change from wood to metal, architectural shapes and ornamentation were considered desirable to make machine tools and other machinery meet what seems to us now the rather barbaric taste of those who were to use them. The same might be said of locomotives, which almost up to the sixties were elaborately decorated with paint, polished brass and scroll work.

Great Britain produced the first good machine tools, and set the example which has tended to simplicity in design. To that country we owe much that is valuable, not only in the direction of self-acting machine tools, but also in the various appliances for improving the character and quality of

work to be accomplished. Thus, Sir Joseph Whitworth, one of the earliest makers of superior machine tools in England, aimed at utility and not ornamentation in the improvement of his products. It was he who introduced surface plates for producing other plane surfaces by means of the scraper; that is to say, after a surface had been made comparatively true on the planing machine, it had yet to be brought to a commercially true plane by a process of scraping off the higher projections, until, when tested by one of the Whitworth surface plates, it seemed to touch at intervals of not more than ¼ inch.

After scraping had come to be recognised as the only means of making true plane surfaces, there followed, unfortunately, a form of deception, the practice of scraping the surface without any special regard to the purpose for which the operation is intended, but rather to give it the appearance of having been carefully fitted, and the surface so produced was very aptly called by the late Mr. William B. Bement, of Philadelphia, "bedquilt scraping." The parts touched by the scraper in this imitation work are very often not irregular in design, but constitute a set figure or pattern which cannot deceive the eye of those familiar with good work.

Long before the time of the International Exhibition of 1851, America had begun to take her place in machine tool building, under a clearly distinct line of thought that was for a long time not appreciated in other countries. When visiting England, in 1884, the writer was shown a copy of an American planer adapted to planing the stub ends of connecting rods for locomotives, there being two sets of uprights and two cross-heads with four tool-holders, adjustable in position to enable both ends of two connecting rods to be planed simultaneously. The American tool from which the idea was taken has its cross-heads facing one another, and the table is speeded to run back and forth at the same rate of cut. By this means the machine is made to take a cut at each forward and backward movement of the table. The British machine had its tool holders facing in one direction, and all four cuts were taken at one and the same time only when the table was running forward, no work being done on the back stroke. The power of the American machine was, therefore, double that of its British copy, all other things being equal, and the maker was astonished when this was pointed out to him.

This one example shows how difficult it is to copy the machinery of another country if the copyist does not grasp the controlling idea of the mind that gave life to the original. Instances of this are found in many other directions where American contrivances, having obtained a world-wide reputation, are less efficient in the foreign copy than in the original production.

The rod planer above alluded to has been superseded in the United States during late years by improved milling machines. Locomotive builders, such as the Baldwin Locomotive Works, have discarded planing machines in fitting up connecting rods for locomotives, making use of revolving cutters, which cutters have been themselves greatly improved not only in regard to the machines operating them, but also by the invention of special machines for sharpening them.

The planing machine is an invention well within the writer's own experience. In the beginning it had the platen, upon which the work is fixed, dragged backwards and forwards by a chain. The first planer that William Sellers & Co. purchased and put into use was one of this chain pattern, and one was introduced in the shops of the writer's father when he undertook to build a locomotive in 1834. At the time of the Vienna Exposition, where machine tools from Philadelphia were exhibited, the engineers sent by the British Government to Vienna to note the progress that was being made noticed the broad feed cut on all the planing machines, lathes and tools that came from all parts of America, and remarked upon it as "producing good effect," as "looking well," etc., as if it were for appearance only, not knowing that it was a principle that

had been established in America, thoroughly understood not only by the managers of the works, but by workmen all over the country, and universally adopted as necessary to good work.

When the early locomotives were built, in the Niles Works, in 1856, the boring of the cylinders was done on a 36-inch lathe with a horizontal boring bar, and without any knowledge as to the theory of boring in order to produce the best results. It always took two days to bore the cylinder of a locomotive of the size in use at that time, and the largest cylinders were not over 15 inches in diameter. In Philadelphia, when Baldwin's had advanced to a very large establishment, they still bored the locomotive cylinders in the same way. It was not until shortly before the Centennial Exhibition of 1876 that attention was turned towards the utilisation of a theory that had come into limited practice some years before as to the improvement in boring metals, the idea being that the quickest and best work can be done in boring by making the roughing cut with a fine feed, removing as much metal as possible by depth of cut, and making the finishing cut with a very broad feed but light cut that would let the cutter pass through the hole to be bored as quickly as possible so as not to wear the cutting edge in passage. That principal was first introduced when Mr. Asa Whitney, of Philadelphia, discovered that chilled cast iron car wheels could be made to compete with the best wrought iron ones and do a greater mileage. If the wheels cast in an iron mould were not allowed to cool naturally, but, taken red hot from the chill, were put into the annealing furnaces and brought up to a heat a little below the melting point, and then allowed slowly to cool, they were found to be free from all internal strains, while wheels taken red hot from the mould would burst into three or four pieces in cooling, showing that there was violent internal strain in metal cast in that way under the tension of the heavy chill on the outside of the tread of the rim. The problem of boring chilled wheels was solved by taking advantage of the fine roughing cut and coarse finishing feed. Mr. Whitney desired to have wheels made interchangeable in their fit on the standard axles, so that when a wheel was fitted on an axle at a workshop in Philadelphia, another wheel could be furnished to fit that same axle at any future time, and just as well as the first one.

When the late Mr. Hudson had charge of the Rogers Locomotive Works, at Paterson, N. J., he applied to the firm of William Sellers & Co. to have a special locomotive cylinder boring machine designed and built, saying that he had seen a boring machine designed by Mr. Grant, of the Grant Locomotive Works, capable of boring a 19-inch cylinder in nine hours. The matter was referred to the writer, and when he came to calculate the theoretical time required for boring a cylinder of the size named, on the supposition that the speed of 16 feet per minute might be used in making the cuts, with a fine feed and a deep cut for the roughing cut, and a shallow cut and a much wider feed for the finishing cut, it was found that the estimated time amounted in all to only three hours, and three and a half hours were named as not only possible, but what might be guaranteed as the productive output of such a machine. An order was given for this machine, it being understood that it was not only to bore the cylinders, but to counterbore the ends for the clearance of the piston, to cut off the sinking head and face up the flanges at each end of the cylinder. When completed, the first test was made with a 19-inch cylinder of hard, close metal. This was bored in three hours and twenty minutes, exclusive of the time of setting the cylinder, which was not much, on account of the peculiar arrangement of the machine, and the facility with which the cylinder could be put in place for boring. In this case the cylinder stood still, while the boring bar travelled lengthwise, carrying the cutter head with it, and upon the two face plates of the driving heads of the machine were arranged automatic slide rests that faced

off the flanges. In this design there was no guesswork, as the principle of fine feed and deep cut on roughing, with very coarse feed and shallow cut for finishing, was in common use in all operations of boring, turning and planing metals, with exact knowledge as to what result was obtainable when the possible speed of cut per minute had been predetermined for the hardness of the metal to be tooled.

About the time the writer addressed the Franklin Institute on the progress of mechanic arts during the last seventy-five years and since then, a remarkable advance was effected in the cutting speed of tools, particularly in regard to machining steel, which is very difficult to tool under ordinary conditions. Already improvements had been effected in the form of the cutting tools, and special tool grinding machines were invented to reproduce such forms. This dates back about fifteen years. In the second place, improvements were made in the quality of the steel used in making the tools and the treatment of such tools, whereby a speed of cut formerly deemed unobtainable has become common practice in the most advanced machine shops.

When steel armour plates were first sent from the forges to the machine shops to be dressed the cutting tools then in use seemed to be of little value. Of late, the armour plates themselves have been still further strengthened to resist the impact of high-speed projectiles. Consequently, an element of greater difficulty in regard to the working of them has been introduced. Cutting tools made of self-hardening steel of the various makes that are in the market can be used to great advantage at a higher rate of speed, and to this self-hardening principle which enables a cutting tool to be used at a speed which would probably draw the temper of any ordinary cutting tool, there have been added new methods of treating the steel which are yet held as secrets, but will be known to the public if patents are taken out for them. It has been impossible to rely upon the skill of the best workmen to attain the highest speed of cut possible; hence the special study of experts in experimental work must be followed up by rigid inspection, to assist the workmen using the special tools, shown to be fitted for the purpose, to the best advantage in actual commercial work. In working steel the first tendency was to reduce the speed of cut even to as low a rate as 4 or 5 feet per minute, while now the speed is increased very far beyond the 18 feet per minute which is customarily used on cast and wrought iron in planing machines and lathes. The amount of talent expended in this one direction in America exceeds vastly that devoted to the subject in other countries.

Dr. John Anderson, in 1876, then in charge of the Woolwich Arsenal, England, was sent to the United States to visit the Centennial Exhibition, and besides acting as one of the judges of the machine tool exhibit, he made an official report as British Commissioner to both Houses of Parliament. Prominent in these reports there was one on "Machines and Tools for Working Metal, Wood and Stone at the Philadelphia Exhibition," in which the following statement occurs:—

"Great Britain certainly can claim the credit of having been the birthplace of modern machine tools, and has done wonders in raising the mechanical standard of perfection, and her influence for good in the advance of civilisation thereby is incalculable; but when we consider the enormously greater area of the American continent, it is a matter of vast importance that tools have taken such a hold of the American mind, which will influence the civilisation of the Western world for ages to come, and will exercise a powerful effect, not only on that continent, but on Australia, China, and the world generally." This, therefore, has a profound significance which can scarcely be overrated.

Again, he said:—"The display of machine tools made by the United States was so vast that only the more salient points can be noticed in a brief report. It showed certainly that the past century has not been passed in idleness, and, judging by the enormous

stride made by them during the past few years, it showed that they have been intelligent students of the best European authorities. It is true to say, however, that the Americans, as a rule, are not copyists; the inventing of clever devices and tools for saving labour seems to be their natural forte, and worthy of the old stock, probably quickened by the peculiarly favourable circumstances under which they live. It was the display made in this section which most conspicuously brought out the enormous strength of America as a producing power. More than a hundred exhibitors had each a large exhibit that commanded the admiration of all who took the trouble to examine them in detail. In this vast array were machines for all purposes, small arms, ammunition, sewing machines, clocks, watches, and all the branches of machine-making and engineering, and almost all were finished in a style superior to that of any former exhibition."

Scientific methods did not enter into the engineering practice of the first quarter of this century. There was little technical literature to help the designer, and the best results which have made American ingenuity appreciated the world over were brought about through careful experiments and earnest effort on original lines. The history of the steam-engine, so far as the American types are concerned, was clearly not the outcome of the books, for what is thus taught under the head of thermodynamics is really a description of what had been accomplished, rather than the cause of the development. The need of technical education was early felt, but the want was not supplied until the generosity of individuals rendered the foundation of technical schools possible. The Government cannot be looked upon to aid in such institutions in the United States as it can in England; yet up to 1884 there was no technical school in existence in London that in any way compared with Stevens Institute of Technology and the Massachusetts Institute of Technology in the United States. Engineering is now taught also in the American universities. At a dinner given to the members of the Institution of Civil Engineers, in 1884, Sir Lyon Playfair, in responding to the toast of "The Universities of Scotland," after those of England had already been discussed by able speakers, astonished his audience by refusing to speak to the toast directly, and entered a strong plea for technical education in Great Britain such as existed at that time in the United States. He said they should not look to Germany and France for the examples of technical schools, but across the Atlantic, where those speaking their own language had already put into practice what Great Britain had so long needed. While the speaker was doubtless correct as to the wants at that time in Great Britain, the technical school of South Kensington was then being organised, and the guilds of London had contributed freely toward its support. Good work had been done by this and other schools, and by the trade schools that have been established in various parts of Great Britain

We are long past the period of empirical work. The steel makers and iron founders now depend upon metallurgists to guide them, while every well-equipped machine shop in the country must have its staff of educated men who are able to reinforce the practical knowledge of those engaged in manufacturing by exact mathematical methods that, in the early stages of our profession, were limited to simple arithmetic.

As indicative of the necessity of education on the part of the working classes, the writer has known instances in which labour-saving machinery that was cheapening the output in a particular class of hardware in America, when introduced into Great Britain failed entirely and brought discredit to the member of the firm who had advised its purchase. A gentleman interested called upon me afterwards and solicited letters enabling him to visit some of the industrial establishments in the United States. Upon his return from these places he told me that all that had been said about the character of the work done by the ma-

chinery in question, not only had been confirmed, but that its merits had been underestimated. He said, however, that, in his opinion, it was impossible to utilise it to advantage with the workmen in Great Britain owing to trade prejudice and trades union regulations. In his opinion, the difference in the character of American workmen and workmen of the same trades in Great Britain was wholly due to the better education of the Americans who are fully two generations ahead of the others. It is perfectly evident that it is impossible to raise the standard of work by means of labour-saving machinery unless the workingmen themselves will see the advantage derived from their ability to do more and better work, and thereby obtain better wages. This is particularly the case when they are called upon to operate machines that do not require constant attention, but where it is possible for one man to attend several machines and earn higher wages than he possibly could if compelled to stand idly watching a machine that required but a small portion of his time to operate. There would be no inducement to contrive automatic machinery unless those who use such machinery are able, without prejudice, to take advantage of the saving in labour attainable thereby.

Some of the leading engineering journals have taken up the question of the advance made in manufacturing in America as compared to European practice, with endeavour to determine the truth of assertions as to such superiority in the American output, so that if such conditions are proved to exist the reason for them might be discovered. The writer has followed this subject with interest, but can only say at the present time that the greater amount of work done by each workman in America under the best circumstances does not apply only to American workmen, but holds equally with good workmen of foreign birth.

An incident was lately brought to his attention by a manufacturer in Berlin seeking the solution of this problem by personal observation in America, who stated that in iron foundries in Germany where the most improved moulding machines had been employed, a skilled moulder could set up eighty snap flasks in a day, while a German workman not yet three years in America, and without the aid of the tools that had assisted the same class of workmen in Germany, was, to his knowledge, setting up 50 per cent. more flasks in a day. There is something, therefore, in the spirit that animates workmen in a free country, where there is a closer friendly relation, if not with their employers, at least with those directly over them and a healthy ambitious spirit is fostered by the certainty of earning higher wages and using their earnings to better advantage in a land where the workman may become a more important factor in local and national politics than seems possible where the monarchical system of government exists.

FOUNDRY CRANES

By Joseph Horner

THE term foundry crane does not denote a type, but an application. All classes of cranes which are used in foundries are also employed elsewhere, in machine shops, boiler shops, and other places. But there are many cranes that are useless in the foundry, because they are not sufficiently adaptable to its work; those that can be employed economically are thus narrowed down to a few kinds. Three broadly defined types only are of service, namely, swinging jib cranes, overhead travellers, and suspended hoists. But these include numerous classes, according to the method of their operation by hand, steam, water, electricity, or air.

In order to form some approximate idea of the kinds of cranes which are required in a large modern foundry it is necessary to note what lies in the day's work. In the early morning boxes have to be opened, castings turned out and run into the fettling shop, and many of the boxes are taken away and replaced by others from the yard or shed adjacent. During the day boxes have to be set in place, levelled, and turned over, tops lifted, and heavy patterns withdrawn, top parts replaced, and metal brought from the cupola and poured. Under a single roof, therefore, whether separated into bays or not, castings may be made ranging often from a few pounds weight each to 10 or 20 tons. Or, again, the work in one large shop will be all light; in another, all heavy. It is clear, therefore, that no single type of hoisting machine will fulfill these varied requirements, and we must be prepared to find a great variety of cranes employed in foundries, even though the types are so few.

Little need be said about the hand cranes, because they are so old and well known, and because their value is constantly lessening in large foundries equipped according to modern requirements. They cannot, however, be passed by without notice, although the custom now is to despise them overmuch. Threatened lives live long, and the hand crane will not die yet, for it still fills a useful place. Its retention is economical under the following circumstances:—

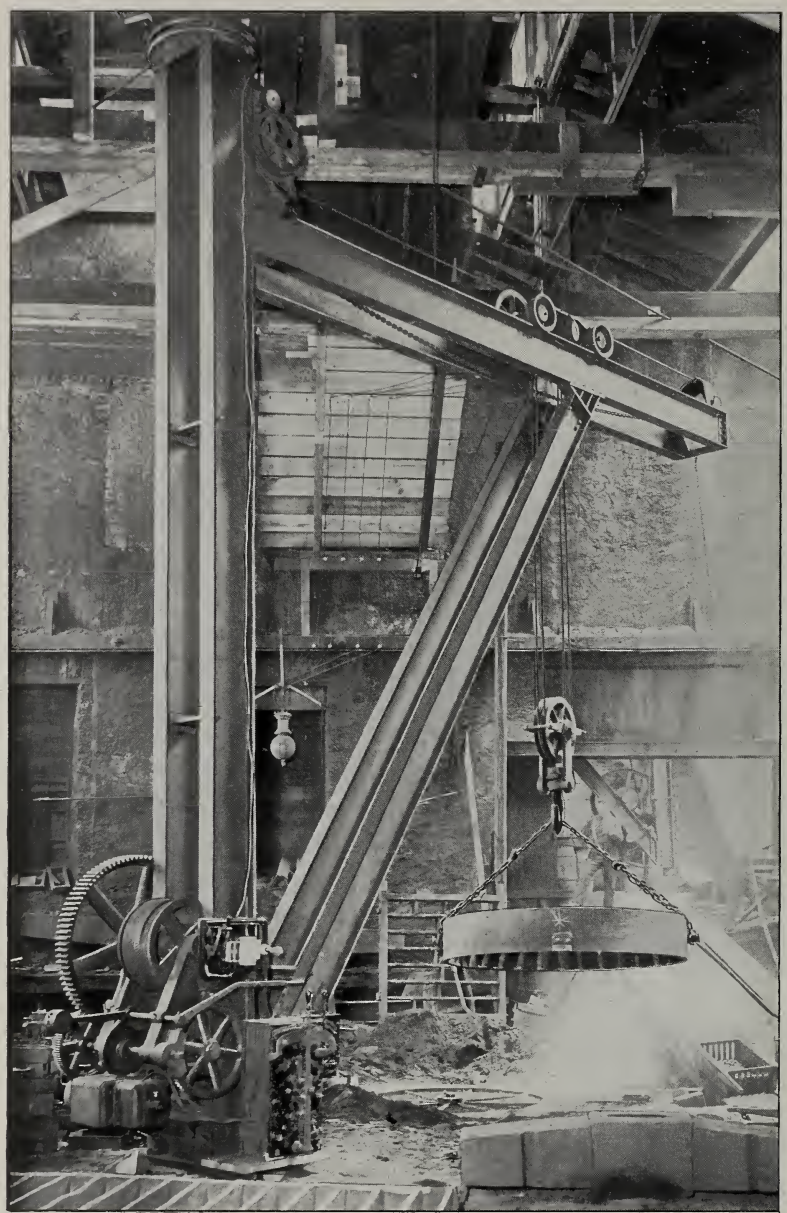
There are many classes of jobs in the moulding of which the service of a crane is required only three or four times during the day,— such as to level the boxes, turn them over, lift the top, perhaps draw the pattern, put on the top part, and pour. Such would be the case in many a piece of work of fair dimensions, the moulding of which would involve, say, one day's labour from the start to the finish; and even though the crane might cover two or three such groups, there would be no time wasted through men waiting for its release by another group adjacent.

The slow movements of hand cranes in such conditions is an objection of little or no moment. All lifting of top parts, drawing of patterns, and turning over of flasks must, of necessity, be done slowly,—very slowly at some stages, even though the crane used should be a high-speeded one, because otherwise damage might be inflicted on the mould. The very slowness of movement of the hand crane and the fact that the moulder can "feel the lift," is an advantage in its favour by comparison with power cranes when these are poorly made. A recommendation to any power crane is its capability for minute ad-

justments and very slow movements. There are also numerous foundries of moderate capacity only, doing a good miscellaneous jobbing trade of an irregular character, in which the laying down of a power plant would not pay for itself by any appreciable difference in output. This class chiefly includes isolated foundries, which are not connected with engineering factories, foundries that work for the trade generally, and for odd customers, and that have no specialty. Electric, compressed air, and water power plants cost money, and require attendance, which would not be justified in such cases, and in these, therefore, it is well to retain hand cranes.

Light hand cranes do good service also under some special conditions, in which they may be occupied nearly all day long. Take, for example, the case of core making, cored work, and light loam work. Cores are rammed up in boxes, or swept against the edges of boards,—work which is carried on in an area set apart from that occupied for moulding. In most shops by far the greater number of the cores made would not exceed a ton in weight. A crane, or a couple of cranes, of 30 cwt., or two tons capacity, and with a radius of fourteen or sixteen feet, would cover the core-making area. The range of vertical lifting required is small, amounting to no more than the lift from the core box on the floor, or from the trestles, to the core carriage in any case, while half the cores made may be rammed up on the carriage itself. After the cores are dried, the shifting from the carriage to a bogie is nothing. Here, then, is a case in which a hand crane is about as

A HAND JIB CRANE THREE HUNDRED YEARS OLD



A 15-TON ELECTRIC JIB CRANE, BUILT BY THE NORTHERN ENGINEERING WORKS, DETROIT, MICH., IN THE FOUNDRY OF THE GLEASON TOOL CO., AT ROCHESTER, NEW YORK

economical as a power crane could be, for the simple reason that the loads are light, and there is no great extent of vertical lift.

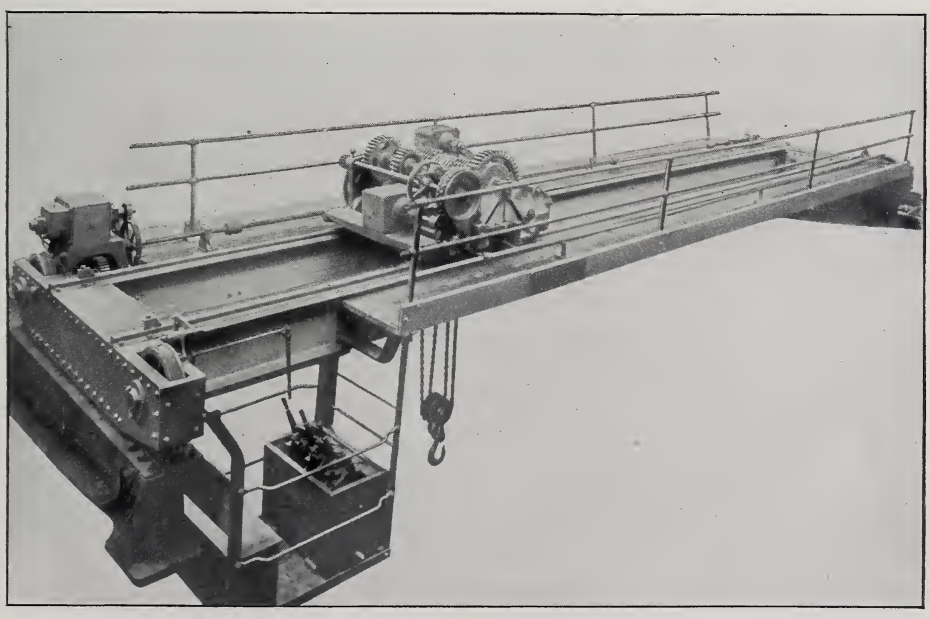
Again, when large work, such as hollow beds and intricate cylinders, is being cored up, from ten to twenty cores may have to be set in place over an area that can be covered by a crane of fair radius. The crane is occupied hour after hour without cessation in trying in cores, and lifting them, to be eased

where required, in carrying them while filleted edges are being rubbed off, and while blackening and final setting is being done. The time occupied in actual lifting is but slight by comparison with the mere occupation of the crane by the cores, which are lifted only high enough for the men to work on them, and they may be lowered quickly nearly to the final position by the brake.

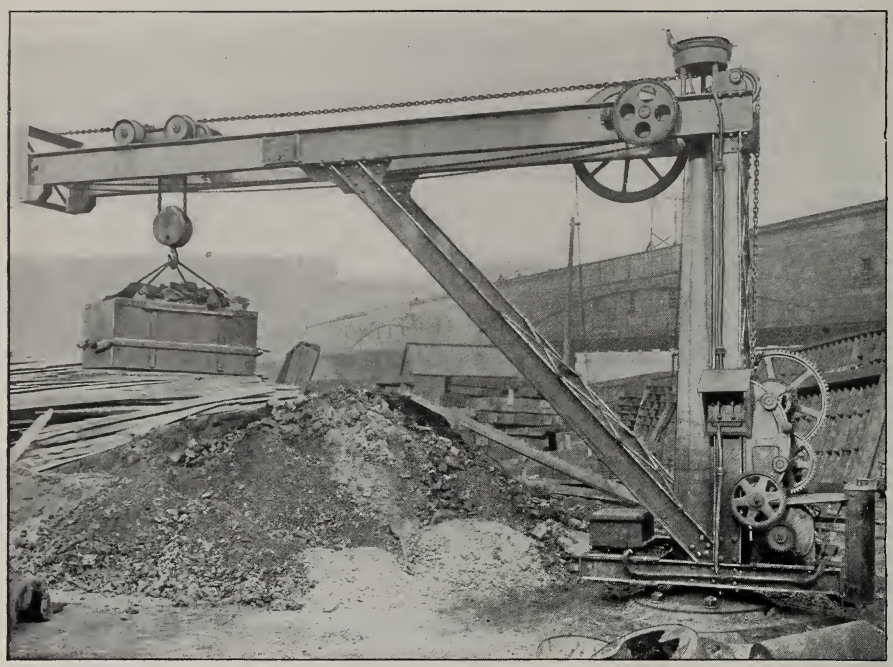
In these cases, typical of others, an overhead power traveller is nearly useless. Its power is not wanted; neither can a traveller in any foundry be kept fast all day by a single small knot of men. It is wanted for the heavier tasks up and down the shop, in handling which lies its chief advantage. The only real rival to the hand crane in the cases enumerated is the air hoist, of which more later on. But this involves a plant which many a small foundry could not well afford.

A very old hand crane is the triangular framed type, in which mast, jib, and strut are constructed of timber. It is clumsy, but stiff and strong, and it has filled an indispensable place in the work of the older foundries. Some small shops even now do their heavy work in a square building, served with a jib crane, hand operated, pivoted in the centre of the shop, and swinging round in a complete circle. The objection is that it blocks the centre space. One drawback to the triangular type of crane framing is that the strut is often in the way when work is being racked inwards, and the larger the width of the box or the mould, and the greater the height of the lift, the less is the effective range of racking movement. When lifting and racking ladles of metal, the timber struts are also exposed to intense heat, which, naturally, is undesirable.

It is curious that this diagonal strut, which is so much in the way, though indispensable in a wooden framed structure, should have been perpetuated so persistently in iron and steel-framed jib cranes. It is a case of slavishly copying the wooden framing in metal, when experience would show how necessary it is to maintain a clear way under the jib right up to the mast. A good type, therefore, of hand jib crane is that in which the jib is sustained by tie rods coming diagonally from the top of the



AN ELECTRIC TRAVELLER MADE BY MESSRS. CRAVEN BROS., LTD., MANCHESTER, ENGLAND



A 3-TON ELECTRIC JIB CRANE OF 20 FEET EFFECTIVE RADIUS, MADE BY THE BROWN HOISTING AND CONVEYING MACHINE CO., CLEVELAND, O., U. S. A., AND LONDON

post,—extended upwards for this purpose,—down to the free end of the jib.

The method of lifting the load in hand cranes varies with the power. There is always a trolley or racking carriage running along the horizontal jib,—which is the only jib suitable for foundry service. The chain or rope passes over a couple of pulleys in this carriage, and is actuated by single or double gearing on the post, or mast, by winch handles. In light hand cranes, pulley blocks are sometimes suspended from the trolley carriage, as in similar cranes used in machine and fitting shops and smithies. Slewing is performed by hauling at the chain or load. The racking movement is effected similarly, except in the heavier cranes, in which the trolley and load are racked along by an endless chain or rope, and spider wheel and gear, at one side. In some cases winch handles and gear are necessary, or at least desirable, to avoid spasmodic and jerky movements.

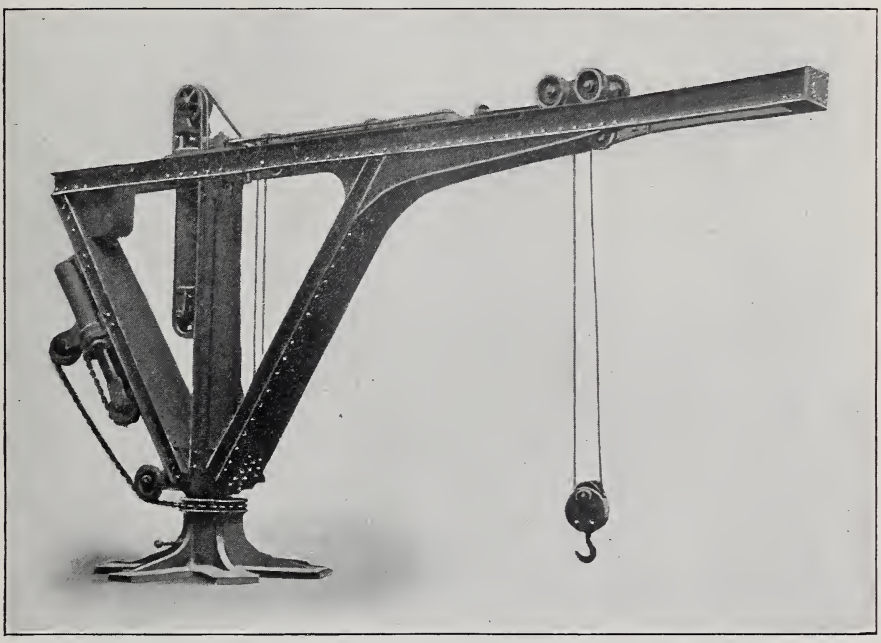
An alternative to the jib crane is the light overhead hand traveller, actuated by dependent chains or ropes. This is as suitable for a small foundry as a jib crane, though usually it is supplemented by light jib cranes. The crab gears are single or double, the winch handles being displaced by the dependent chains and spider wheels. In some very light travellers there is no crab. A single girder of I section, in some cases a pair of parallel girders, carries a light trolley carriage, from which pulley blocks are suspended and operated by dependent chains. The trolley is traversed along the beams, and the beams travel longitudinally. The pulley-blocks are self-sustaining.

Hand cranes, except under the circumstances just named, should have no place in foundries which are laid out with regard to economical handling of work. In many small foundries, and in all those of large size, power cranes are essential. Difficulty is often experienced in making a selection from the numerous types available. In many instances the choice is narrowed down by the nature of the power already in ex-

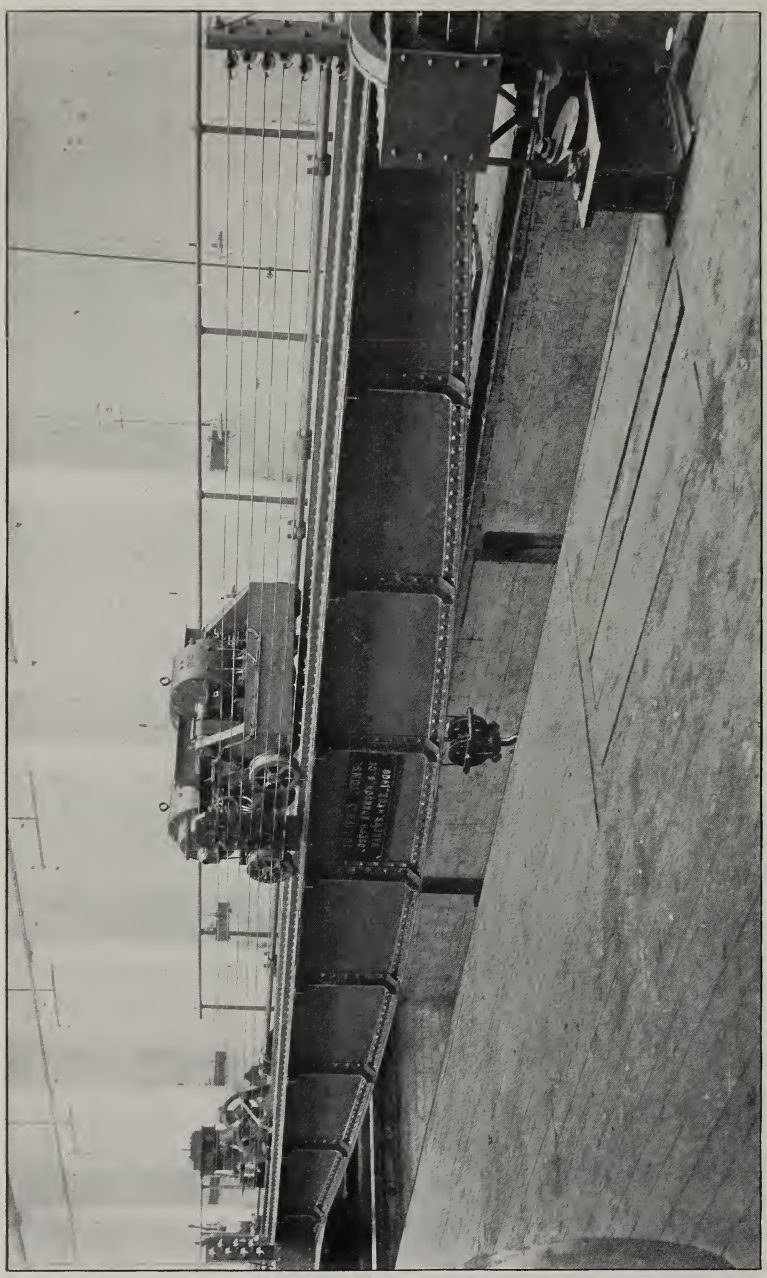
istence,—whether a steam, or electrical plant, water pressure, or compressed air. But large firms would sometimes be well advised to make the question of power subservient to the handling of the cranes most suitable to their work, and to lay down a power plant which would be of general service in view of extensions,—a question of which the importance will be grasped better when we have arrived at the end of the study of foundry cranes.

Steam as a motive power, to be used directly in actuating the hoisting machines in an iron foundry, is less desirable than any other. In the case of jib cranes, steam has to be brought along a length of piping to the top of the post, and carried down through a swivel joint to the cylinders. This joint involves the mutual fitting of numerous parts, with stuffing boxes. Condensation is likely to take place about this joint and in the cylinders, especially when the crane is used very intermittently, as it generally is. There is, besides, an absence of simplicity about the whole arrangement, while no compensating advantage is gained by complexity. These are the reasons why steam is less favoured now than other motive powers in the operation of foundry cranes, notwithstanding that other machinery in and about the building is still mostly driven by steam and belting.

In the case of a traveling crane the direct use of steam involves one of two devices. Either the engine and boiler must be on the traveller at the end, actuating a jenny through ropes or chains, or else they must be on the crab; or the engine must be fixed at one end of the shop and the power be transmitted to the traveller through a square shaft, or rope, which must extend along the whole distance of the longitudinal travel. A square shaft must be supported by numerous bearings. Another square shaft must run alongside the traveller bridge to operate the cross traversing and the lifting movements of the crab, and must also be supported by tumbling bearings. These details have only to be mentioned to show the utter



AN HYDRAULIC CRANE MADE BY MESSRS. HENRY BERRY & CO., LTD., LEEDS, ENGLAND



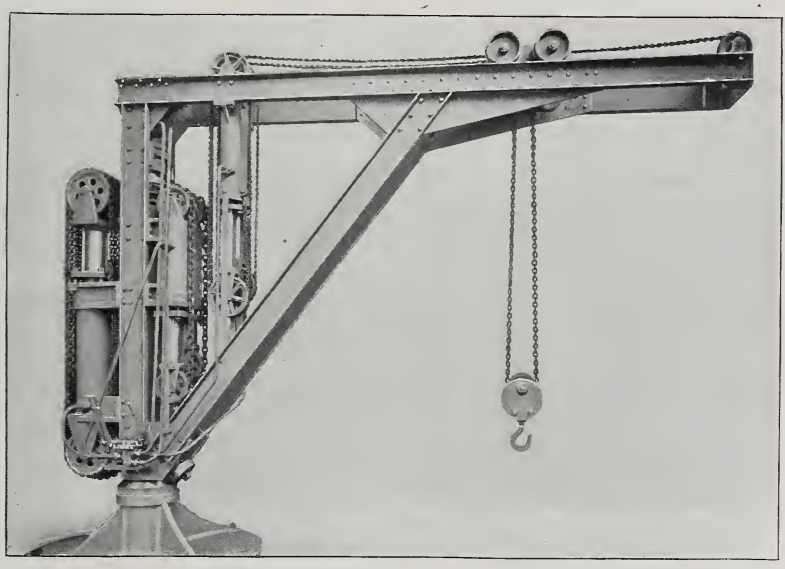
A THREE-MOTOR ELECTRIC TRAVELLER BUILT BY MESSRS. JOSEPH ADAMSON & CO., HYDE, CHESHIRE, ENGLAND

wastefulness and clumsiness of the system. The best method of utilising steam in the overhead traveller is by means of cotton ropes carried along one of the runways. This drive has been brought to a high degree of perfection, and would doubtless have occupied ere now a large field of foundry service, from which it promised to displace the square shaft drive, but for the advent of the electric traveller.

Hydraulic jib cranes are far preferable to steam-driven ones in the foundry. They are of three broad types. In the simplest of all,—direct acting,—the hook is attached to a trolley carriage which runs on the jib to give radius, while the lifting and lowering are done by the vertical movement of the jib itself. This is effected through an inverted direct-acting hydraulic cylinder moving in the mast upon a fixed ram, or through a movable ram in a fixed cylinder. This lift is ideal in its simplicity and smoothness of movement, perfect regulation, and with no chains or pulleys interposed. Such a crane is usually racked and slewed by hand.

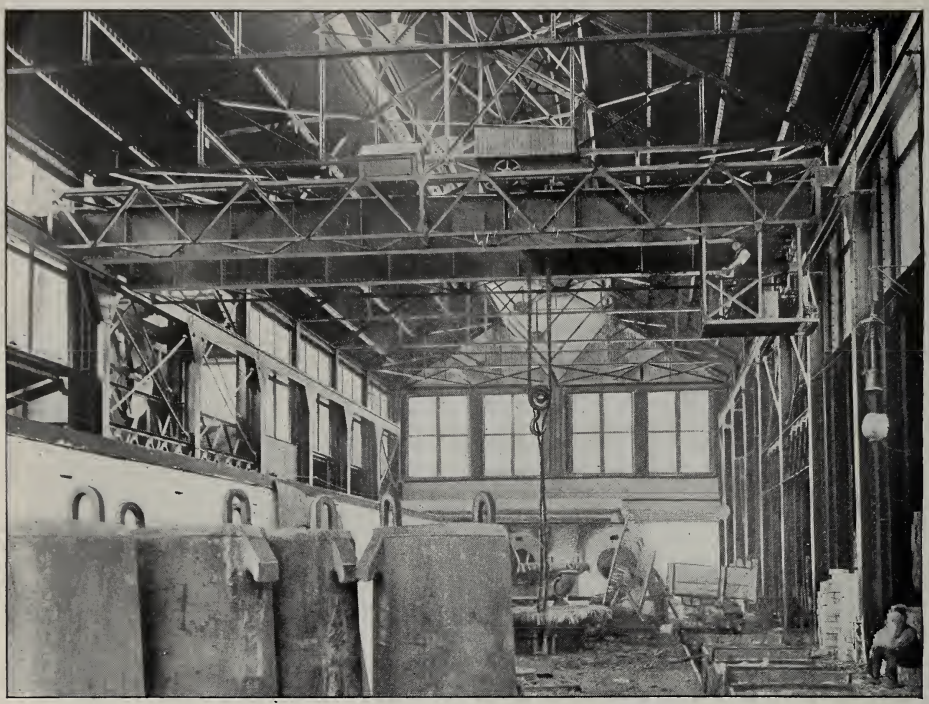
In a more advanced type, an ordinary lifting cylinder with pulleys and chains is fixed in the mast, and the chain passes thence to a trolley carriage on a fixed jib. The carriage is racked by a spider wheel and independent endless chain, and the slewing is done by hand.

In the most complete type,—adopted in cranes lifting, say, from two or three tons upwards,—the cylinder in the mast is fitted with two telescopic rams, for light and heavy loads, respectively, so avoiding waste of water when lifting light loads. The chain passes to the trolley carriage, which is racked by separate cylinders, placed on each side of the jib. Cylinders for slewing by power are located behind and below the mast.



AN HYDRAULIC JIB CRANE MADE BY MESSRS. RICE & CO., LEEDS, ENGLAND

A wide choice is thus afforded in jib cranes operated by water pressure, and these are deservedly popular. The smoothness of their motion is favourable to foundry work in which fragile moulds and molten metal are handled, and their movements are capable of very exact regulation. But for the fact that an hydraulic installation of pumps, accumulator, and pipes is required, their use would have been more general than it is. Another point is that during recent years other and more novel types of cranes and hoists have come into rivalry



AN ELECTRIC TRAVELLING CRANE MADE BY THE BROWN HOISTING & CONVEYING MACHINE CO., CLEVELAND, OHIO, U. S. A., AND LONDON

with the hydraulic crane. Nevertheless, in places where an hydraulic plant exists for boiler shop machines, and for testing purposes, these cranes are found, and in such cases they are economical and entirely satisfactory for foundry service,—within the limits of the operations which can be fulfilled by jib cranes.

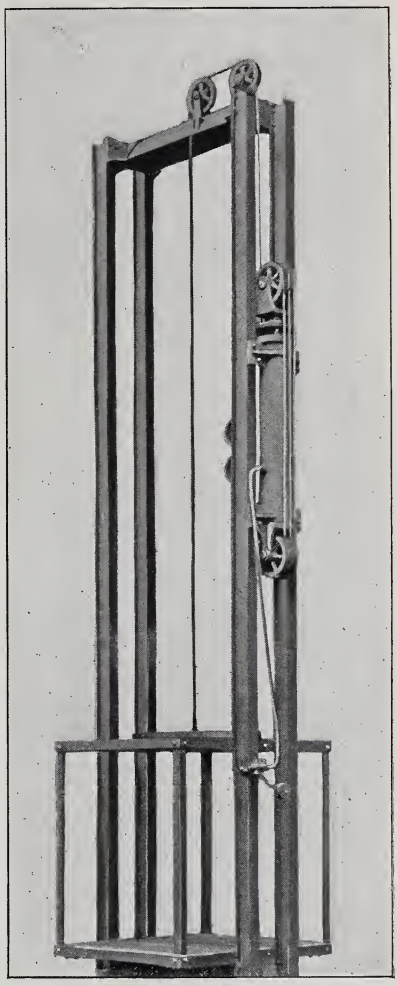
The overhead power traveller is a rather late arrival in the foundry; it was unusual to see travellers of any kind in this department until recent years, the jib cranes monopolising the entire service. There sult was that several men had to lend a hand when heavy lifting and turning over was being done. Heavy flasks, in the absence also of floor tracks, were dragged by sheer force of human labour on trolleys along the sand floor, or tumbled over on edge by a gang of labourers. Metal was carried by two, three, or four men at shank handles, and ladles exceeding about 3 cwt. were slung with a changing hook from crane to crane adjacent down the shop. The expenses for unskilled labour with such crude appliances were, and are still with some firms, a heavy tax on production. Though light travellers operated by dependent ropes were employed much in small shops, the steam travellers,—square shaft, and cotton rope types,—were not installed to any great extent. In fact, at one time it was believed that power cranes could not be made sufficiently steady and slow in action to lift copes and to draw patterns without risk of starting the sand. That achievement, however, has passed into the realm of fact, and a well-made modern crane will operate either rapidly or slowly, at will.

Hand travelling cranes, the square shaft power type, and the self-contained overhead steam travellers may be dismissed at once as unsuitable for a new installation in any large foundry where economy is a consideration. The first is too slow; the second and the third

absorb too much power, and are noisy and dirty, besides being, in several respects, unhandy. The cotton rope traveller, when well made, is an excellent crane, but is not so convenient from some points of view as the electrical type; neither is it so economical. The case for a cotton-rope traveller would be that in which no electric plant exists. But even then it would, in many cases, be well to consider the desirability of putting down such a plant. The unhesitating opinion of the writer is that, in fitting up a foundry with a new traveller, or travellers, the most economical and convenient to employ is the electric. Such a conclusion follows from the considerations already adduced.

There is more difficulty in selecting an electric crane from the many offered than in deciding on the type, because among the best cranes now made the choice is narrowed down extremely. The modern electric traveller, as made to-day by a few leading firms, is the best piece of hoisting machinery now manufactured, the construction of some of its more vital parts being equal to that of good machine tools. We shall, therefore, at once dismiss the types just enumerated and consider in detail the adaptability of the electric traveller specially to foundry service.

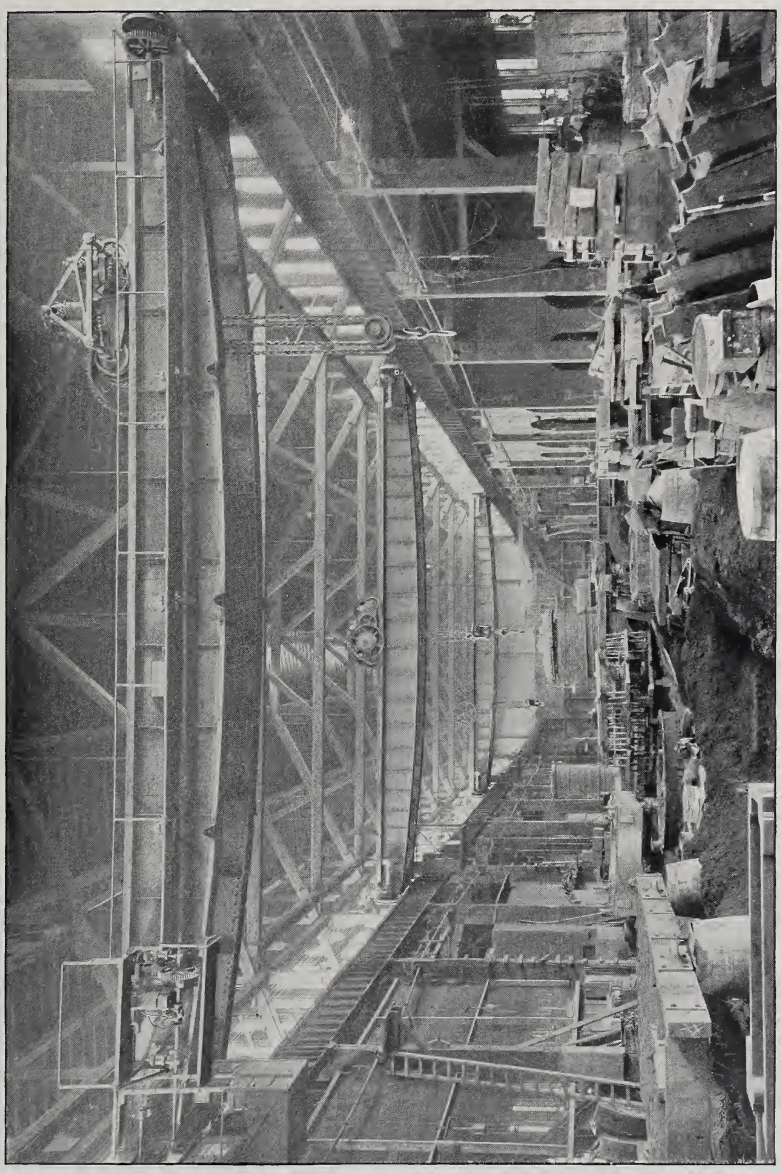
The first question to be considered relates to the system adopted for operating the gears used for hoisting and traversing, in which that for travelling the bridge itself must also be included. At the present time, when reversible three-motor electric travelling cranes have reached a high stage of development, it seems that the question of employing a single-motor traveller should be considered only when the problem is one of the conversion of an existing crane. To order a new single-motor crane is to ignore the obvious advantages of the all-electric type, and the practice and experiences of recent years. When, however, a firm has a good square-shaft traveller, or, better still, a cotton-rope crane in good condition running in its foundry, then the question of dispensing with the shaft or rope and substituting a conductor and single motor may be legitimately considered. In a shop of no great length the economy of this conversion would not be so great as in a larger one. A converted traveller might be operated for a few years until the time arrived for the installation of a new crane of the all-electric type.



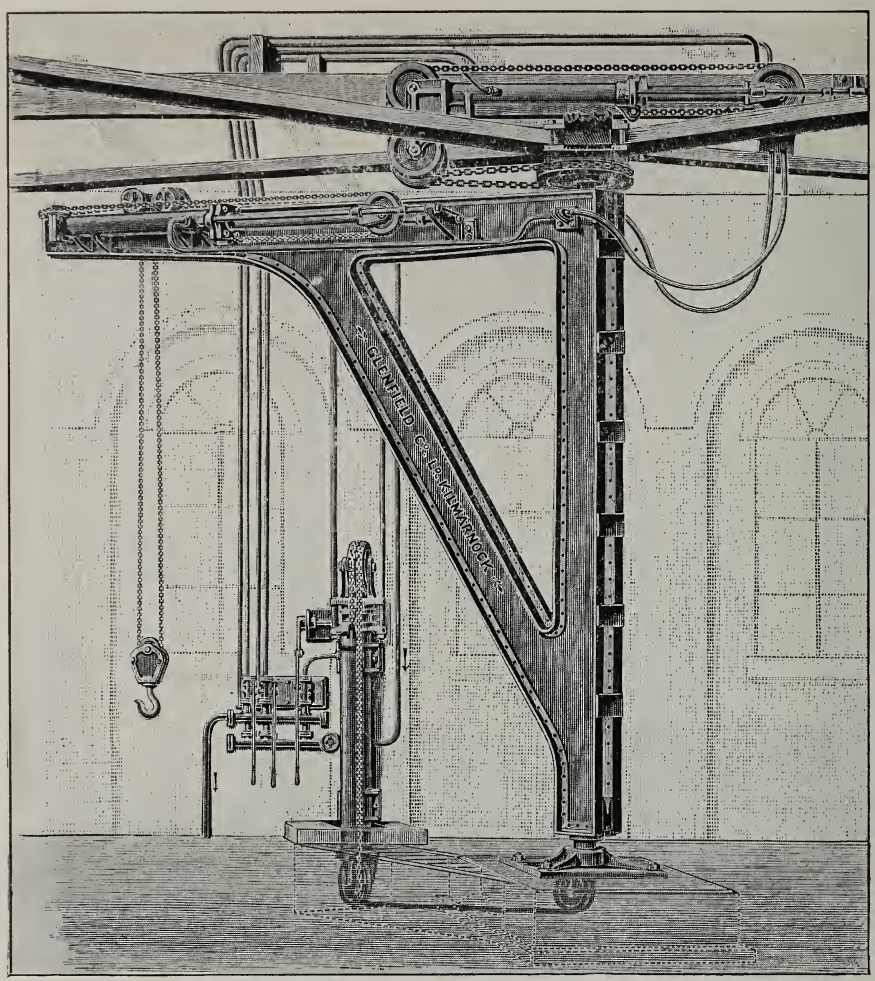
AN HYDRAULIC FOUNDRY CUPOLA LIFT, MADE BY MESSRS. HENRY BERRY & CO., LTD., LEEDS, ENGLAND

It seems, therefore, hardly worth spending time now in discussing the arrangement of single-motor travellers. Their disadvantages are so obvious that they need only to be stated to be evi-

AN ELECTRIC TRAVELLING CRANE MADE BY MESSRS. WILLIAM SELLERS & CO., INC., PHILADELPHIA



THE FOUNDRY OF THE E. P. ALLIS CO. AT MILWAUKEE, WIS., SHOWING THREE 30-TON ELECTRIC TRAVELLING CRANES BUILT BY THE SHAW ELECTRIC CRANE CO., MUSKEGON, MICH., U. S. A.



HYDRAULIC CRANE MADE BY THE GLENFIELD COMPANY, LTD. KILMARNOCK, SCOTLAND

dent. The great objection to the converted cranes, and to new ones of that class, is the waste of power, due to the continual running of motor, belts, or gears; to the complication which these mechanisms add to the crane; to the great amount of friction, and, generally, the clumsiness of reversing the motions through intermediate gear, instead of at the motor, and driving directly therefrom. We may proceed at once to point out the leading characteristics which should be, and are, possessed by the most advanced types of reversible three-motor electric travellers.

In the first place, prejudice exists even now against the employment of such cranes at all in foundries, by reason of the dust and sulphur which might prove injurious to the motors. With open motors that objection would have force. But several firms in Great Britain, America, and on the Continent encase the motors in neat iron boxes, for use in dirty shops, making them absolutely dust-proof. Some of the smaller high-speed gears are also encased, so that none of the vital parts can possibly receive injury from dust.

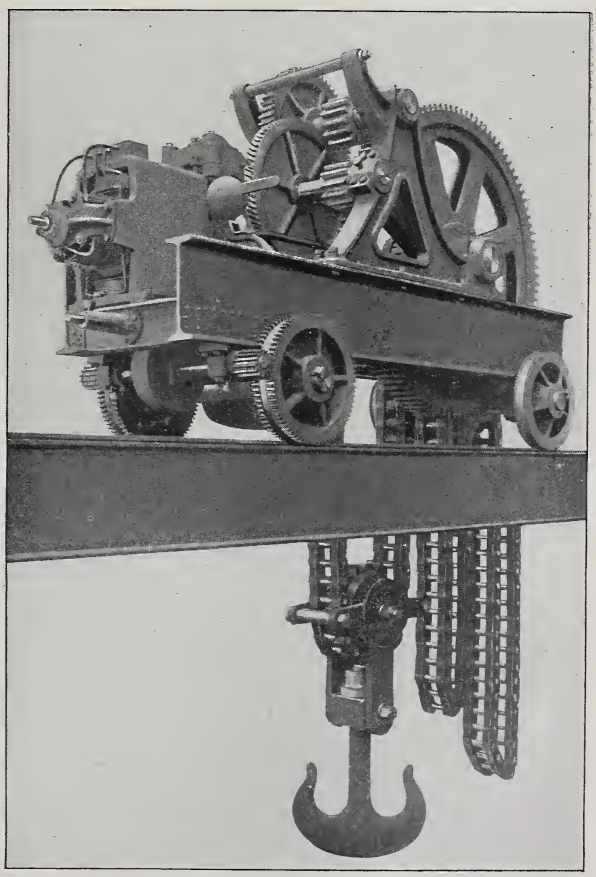
The movements of modern travellers are more rapid than those of their predecessors. But a high speed of lift is

of less value in a foundry traveller than mobility. A quick rate of cross traverse is more important than quick lifting, and in a long foundry rapid longitudinal travel is still further desirable. Comparatively few rapid lifts are ever necessary, but the rate at which the other two movements are effected is a measure of the speed of transit of materials and tackle about the shop, and makes the principal difference between the cost of power carrying and that effected by hand, or by crude mechanical, methods. High travelling speed is of value not only in relation to the work of the traveller itself, but also to that of the wall cranes, for the quicker the traveller is able to move from one job to another, the fewer will be the number of wall cranes required.

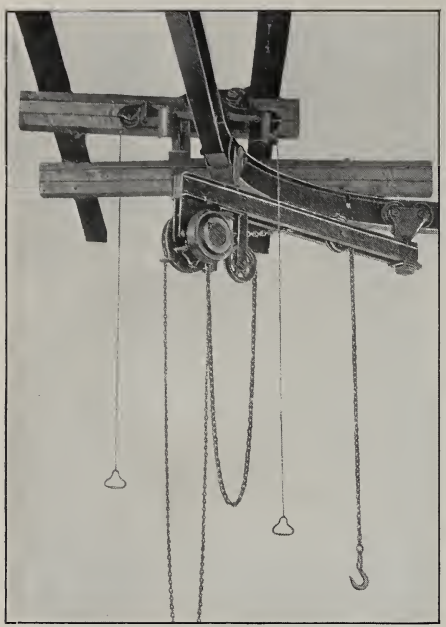
The anticipation that these, or their equivalents in the form of hoists on overhead trolley tracks, can ever be superseded by the heavy traveller is not to be indulged in, but their numbers may be lessened by a judicious selection of a traveller possessing a high degree of mobility. Special attention has, therefore, been given to high rates of travel in the best later designs, the rate increasing approximately with increased shop lengths. Almost any speeds in reason that may be thought desirable may be obtained, subject to conditions imposed by the size and the power of the cranes.

With high travelling speeds, the risk of lateral weakness, tending to bending, over setting, and cross working, has to be carefully guarded against by a general stiffening-up and widening of the main girders, and lengthening of the wheel base. The most common construction, — the fish-bellied type of bridge girders,—with the crab or trolley running on the top flanges, has, therefore, found rivals in the parallel girders, between which the trolley runs, as in the Sellers traveller, shown on page 224, and in the type of the Brown Hoisting and Conveying Machine Company, on page 222, built of lattice framing, and stiffened laterally with broad horizontal lattice girders.

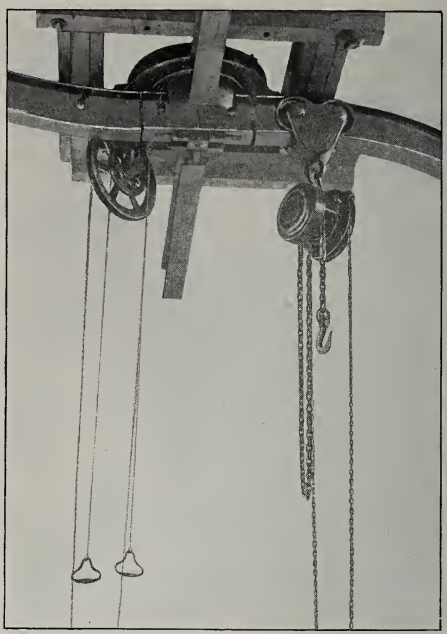
The Sellers design is a good one, stiffness being secured by connecting and reinforcing the tops of the bridge girders by means of bracing; the trolley runs on rails between the girders, underneath the braced work. The removal of the heavy mass of the crab to the lower part of the bridge tends to



A 65-TON ELECTRIC CRANE BUILT BY THE OERLIKON MACHINE WORKS, OERLIKON, SWITZERLAND



WESTON TRIPLEX BLOCK ON OVERHEAD TROLLEY



TURNTABLE FOR OVERHEAD TRAMRAIL

INSTALLED BY THE BROWN HOISTING & CONVEYING MACHINE CO., CLEVELAND, U. S. A., AND LONDON

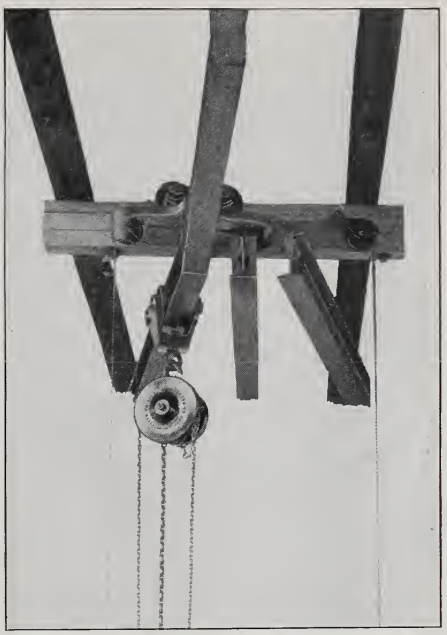
more stable equilibrium, while it permits of the top bracing which obviously cannot be introduced when the crab or trolley runs on the top flanges of the girders. The lateral truss bracing of the Brown Hoisting and Conveying Machine Company makes a rigid framing. Its width is not objectionable, because the crab cannot be brought nearer to the end walls of a shop than is permitted by the end carriages, and the trusses do not extend beyond these. There can be no lateral weakness or cross working in such a design. It is an original departure, which has found much favour in the United States. When neither of these devices is adopted, then the flanges are stiffened sideways, either by widening them, to which there are limits, or by riveting large angles down the outer edges, or by increasing the thickness of the top flange. Cross working in the Adamson cranes is prevented by reinforcing the connection of the main girders to the end carriages with broad gusset plates.

In the designs of crabs or trolleys, though the ideas of firms differ widely in relation to details, yet the following are essentials:—Compact arrangements, the reduction of gears to a minimum, stiffness in side frames and cross girders, bushed bearings, good bearing surfaces, large, stiff shafts, cut teeth for all the high-speed gears, and suitable locations of motors. The frames may be of cast iron, either of the box type, or ribbed, or steel plated, parallel, or cambered in outline.

It is now recognised as being desirable to use low-speed motors for travellers. This is quite contrary to the early practice, but is in entire accordance with the best of the present time. The advantage is that there is less reduction gear, less wear and tear, and that the motions can be stopped and reversed quickly. Motor speeds of from 250 to 700 turns per minute mark the limits of the best practice, and a good average for medium work would be found at about 400, subject to variation according to whether the motor is for a light crane or a heavy one, for lifting or travelling motions, etc.

Even these speeds, however, are high

OVERHEAD TROLLEY IN A FETTLING SHOP



DOUBLE SWITCH FOR OVERHEAD TRAMRAIL

INSTALLED BY THE BROWN HOISTING & CONVEYING MACHINE CO., CLEVELAND, U. S. A., AND LONDON

for first-motion shafts by comparison with those of the older, slow-moving cranes. The immediate result has been a necessary improvement in the toothed gears used on electrical cranes. Cut gears were a novelty in crane work only half a dozen years ago. Now there are many electrical travellers in which the only cast gears are the barrel wheel and its pinion. The difference in regard to smoothness of operation and freedom from noise is immense. A leading British firm employs a nickel-steel pinion forged in one with the motor spindle, to gear with a bronze toothed ring at the first speed-reduction shaft. Bevel wheels are now not used at all on the best cranes, all speed reductions being effected by spurs, while changes in direction of motion are avoided by arranging the motor spindles parallel with the direction of rotation desired.

There is little question that the worm, used so long for driving the trolley or crab gears, will disappear entirely from the best practice. Several firms have already dispensed with it. It is, after all, but a survival from the old travellers, when there was no other practicable method of operating the cross traverse and the hoisting gears except through sliding worms or bevel wheels. It has proved a wasteful device,—a matter of less moment, however, in the slow-moving crabs than in those of later design. In present practice one motor drives the travelling axle of the crab or trolley through spur wheels, and another actuates the hoisting drum through spur gears.

But though not retained in service in this application, the last word has not been said for the worm gear; so much depends on how it is made. The efficiencies are very different in a single-threaded worm working in a badly cut, or cast, wheel, and a treble, or a four-threaded, worm working in a hobbed wheel, and running in an oil bath, with a thrust bearing in oil. But the worm has got a bad name which sticks, and, everything considered, it is better that it should disappear from the main drives of the electric travelling crane.

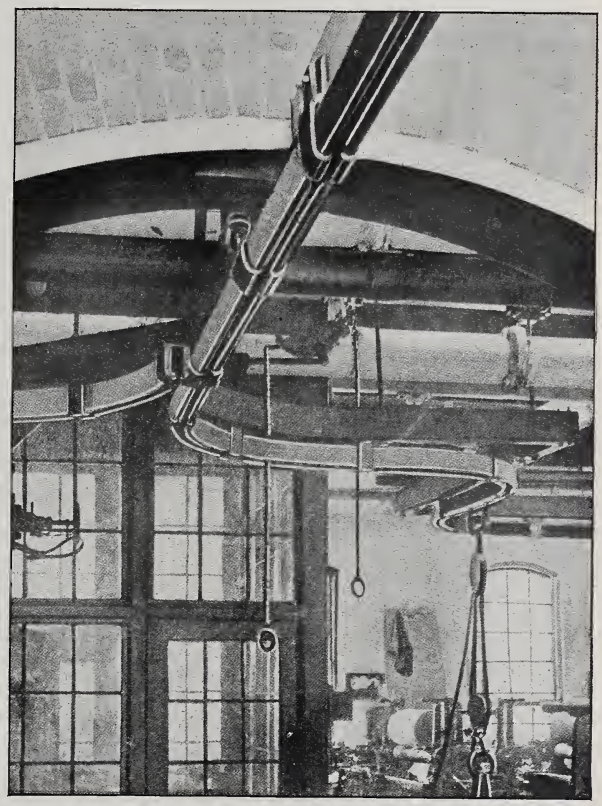
One of the crowning advantages of the three-motor traveller is that no

THE FOUNDRY OF THE LANCASHIRE & YORKSHIRE RAILWAY WORKS, HORWICH, ENGLAND

change of gear for effecting changes in speed is necessary, since the series-wound motor and the resistances combine to produce high speeds with light loading, and reduced speeds with increased loading, as the switch is moved over the contacts. The introduction of the series-wound motor into crane work has thus proved a very great advantage.

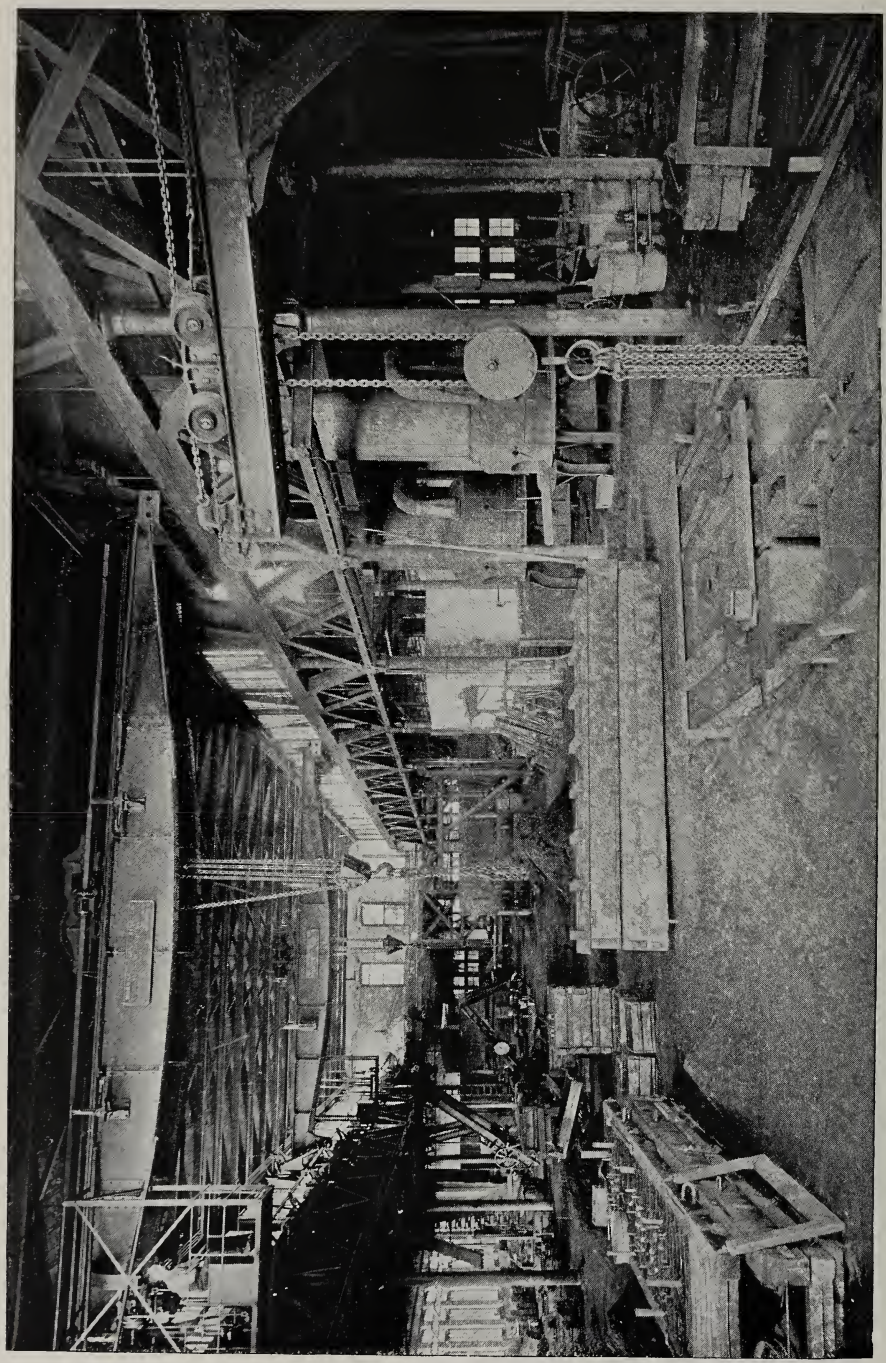
Change in gear in ordinary crabs is a slow process, because the attendant has to get from the cage to the crab to effect it. One result is that, rather than change gears, loads are often lifted at an unsuitable speed. Yet an important point in any foundry crane is a wide range both in speeds and powers. The power crane should be capable of operation much like the hand crane. The handles of the latter at one moment will be moved round at an extremely slow pace, when starting a cope, or pattern, or setting a core, or a cope, the labourer taking his instructions from the moulder. But preliminary lowering will be done rapidly with the brake, and ordinary lifting will be accomplished at as high a speed as practicable. Changes are effected from slow to quick gear when a light load has to be lifted rapidly, by slipping a shaft or a gear along, —a movement quickly made.

Many moulders like hand cranes because of their great handiness, and they are, in fact, preferable to unsuitably designed power cranes. Now, though much slow work must be done with the power traveller, rapid movements are also desirable, and in this lies its advantage over the hand crane. Nearly all power cranes, therefore, except the very lightest, have changes of gear from slow to quick, from high powers to low, two changes being the limit in most cases. But the best electric cranes have no such change. The speed is capable of regulation from the maximum to a movement so slow that a pattern can be drawn at an almost imperceptible rate of lift, and so well under control that the motion can be arrested or its rate accelerated instantly when the pattern has cleared the mould. The same precision is attainable similarly in the travelling and the cross transverse movements, each of which can be easily started and stopped within an inch in a good crane.



A SYSTEM OF OVERHEAD CARRYING RAILS MADE BY THE COBURN TROLLEY TRACK MFG. CO., HOLYOKE, MASS., U.S.A.

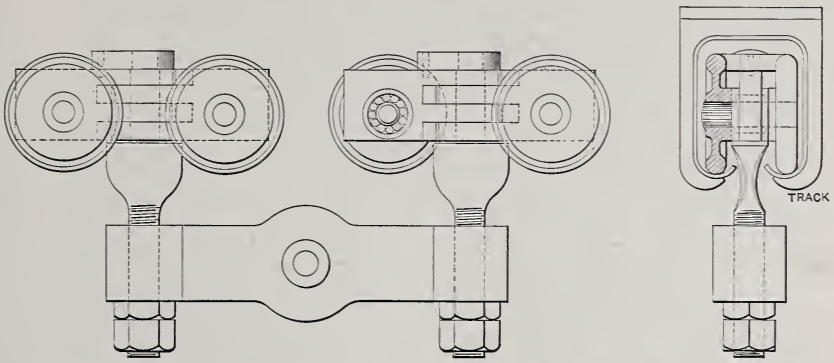
In cases where there is not enough work to keep a man employed constantly in the cage, the motions can be operated from the floor through depending ropes. The name of each motion is engraved on a brass plate attached to its handle. The switches are fitted as though for insertion in a cage, the ropes



TRAVELLING AND OTHER CRANES IN THE FOUNDRY OF THE FOND MACHINE TOOL COMPANY, AT PLAINFIELD, N. J., U. S. A.

being added to the hand-operated wheels. It is perfectly easy to locate the traveller within an inch by the ropes from below.

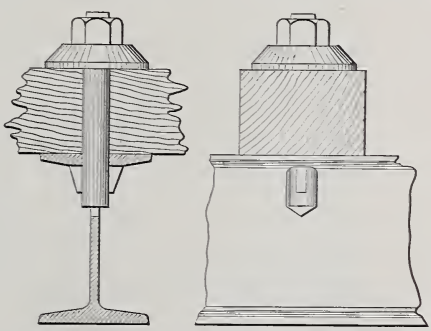
A neat addition has been made by three or four leading firms to the ordinary crabs in the shape of an auxiliary hoist for lifting light loads which range from one-fourth to one-tenth that of the maximum load of the main hoist. The gain is in increased speed, and in saving in power, only about half that absorbed by the main hoist being used for the auxiliary, since the auxiliary barrel is usually operated by its own small motor. In most foundries the hoisting drum is lifting maximum loads only during a very small portion of the time; hence the great utility of the auxiliary barrel.



CARRIER WITH DOUBLE KNUCKLE JOINT TO SWIVEL WHEN GOING AROUND CURVES. MADE BY THE COBURN TROLLEY TRACK MFG. CO., HOLYOKE, MASS., U. S. A.

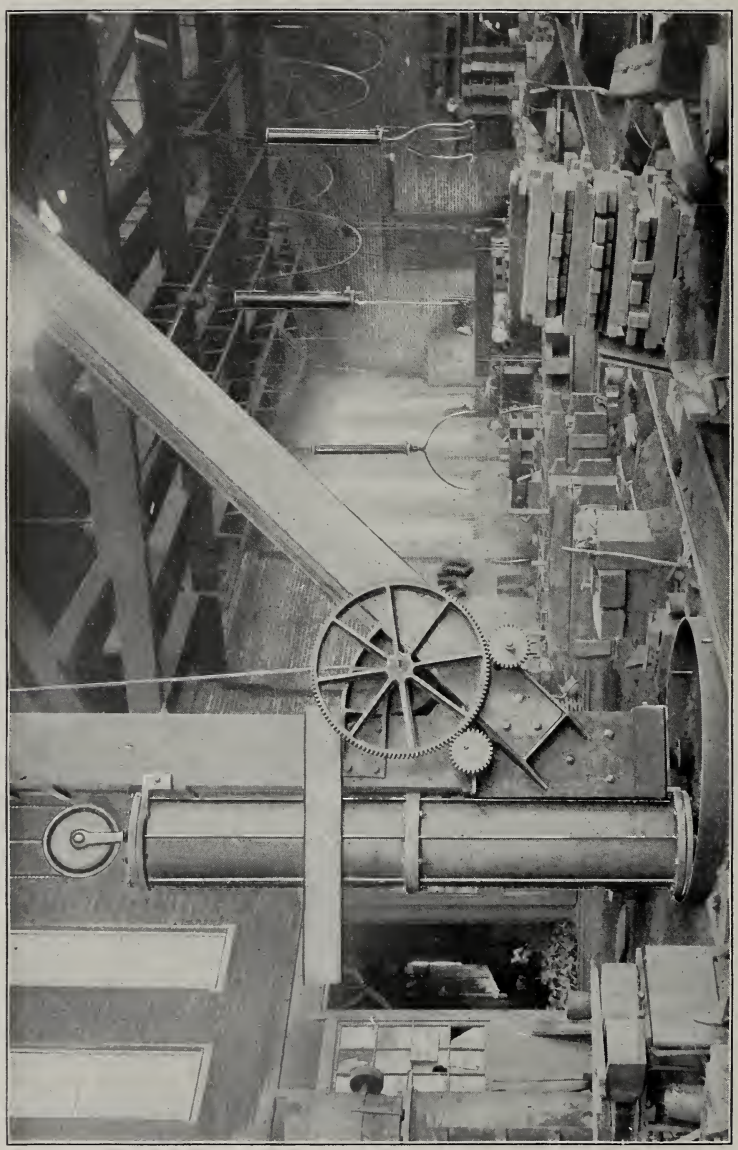
The following practical points refer to the details of most types of cranes and travellers for foundry use, irrespective of their method of operation. Except the possibility of fracture of a chain or any portion of the mechanism, there is no risk more frequently present in the mind than that of a load running down while in the crane. Hence the necessity for a reliable brake, or brakes. The braking action is not always safeguarded as well as it might be, being left wholly dependent in most hand and power cranes on the human element. In some of the better class of cranes the application of friction clutches in combination with screws is a safeguard.

There is no difficulty on the score of good braking with electric travellers, because the electric brake always comes into operation automatically when the current is off, and the current must pass before the brake can be lifted. It is, therefore, more powerful and reliable than those used in any other class of crane. In addition to the electrical, a mechanical pawl and ratchet brake often supplements the electric one. That of the Brown Hoisting and Conveying Machine Company is fitted with two pawls, acting alternately, which are thrown out of action during lifting and into engagement directly the hoisting ceases. The brake pressure is exercised through Weston friction discs.



TYPE OF HANGER BOLT USED BY THE BROWN HOISTING & CONVEYING MACHINE CO., FOR SECURING TRAMRAILS TO OVERHEAD SUPPORTS

With increase in the power of travellers the use of wire rope has largely displaced chains, the links of which are

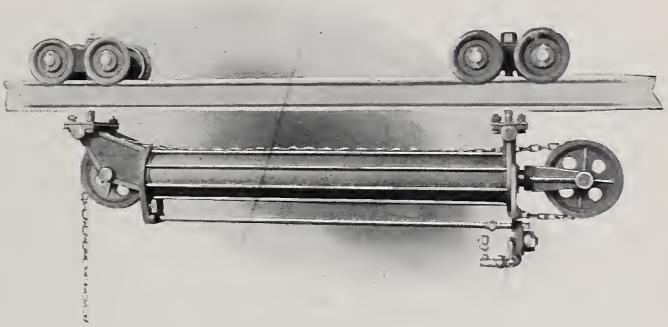


AN AIR HOIST APPLIED TO A JIB CRANE. MADE BY THE CURTIS & CO. MFG. CO., ST. LOUIS, MO., U. S. A.
IN THIS VIEW ALSO ARE SHOWN A NUMBER OF AIR HOISTS USED WITH OVERHEAD TROLLEYS

stiff and subject to much surface friction. There is less risk of damage to the more flexible rope, and less chance of accident, for chain links deteriorate and will snap in time, unless they are periodically looked after and annealed. This may be done by heating them for a night in a stove or furnace and allowing them to cool down slowly. The links must be tested every few weeks by tapping them singly with a hammer. An incipient flaw can then be detected by the sound.

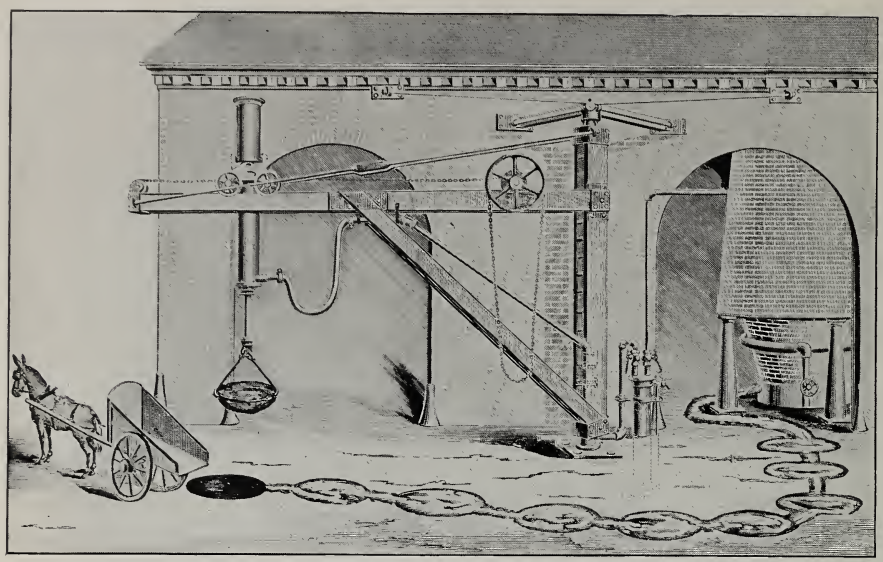
Chains are further objectionable on foundry cranes unless the precaution of grooving the barrel or drum is adopted. Without this precaution the links are apt to slip and cause a surge of the chain, and a jerk which is liable to damage a mould, or, if metal is being poured, to cause a splash. For this reason, too, a double lap of chain is bad practice, as being likely to produce overriding. The same remarks apply to wire ropes, though not in so pronounced a degree. All drums should be grooved for security, and all should take the total lift of chain in a single lap. In travellers with snatch blocks, the ropes should wind on a double spiral barrel, from centre to ends, to keep the load central. In high-power travellers it should wind on two barrels. It is essential, in order to permit of the adjustment of moulding boxes and of ladles of metal, that the hooks of foundry cranes swivel freely. For small hooks the insertion of a common swivel joint suffices, but in heavier ones the necks of the hooks must turn on anti-friction ball bearings.

The immense value of the overhead traveller in a shop built on modern lines in one long bay, or several bays, should not blind those who have to lay out foundries to the fact that a traveller will not perform the whole range of work, since it cannot be serving an entire shop at the same time. There are certain periods in the day when more calls are made upon it than at others. The early morning, when boxes are being emptied, and, later, when moulds are being poured, are generally the busiest times. To multiply the travellers is open to the objection of being a costly method, and one ill adapted economically to the rapid handling of light lifts of from two or three cwts. to a ton. Small supplementary light cranes or hoists are, therefore, indispensable. Most foremen would rather give up the traveller than their small cranes. And as the weight of castings lessens, the value of these cranes increases as that of the traveller diminishes until a shop, engaged wholly with light work, would have little use for an overhead travelling crane. Similarly, at the other extreme, the light cranes are of small value in foundries dealing chiefly with heavy castings. A special value of the little crane lies in this, that a small group of men can have one all to themselves, instead of being delayed until the traveller is released by another group. For some kinds of small work, as in moulds which are quickly made, the crane is in constant demand for lifting and turning over, setting cores, pouring, and emptying boxes, and here the service of light, easily handled, highly mobile cranes is most valuable.



A CURTIS AIR HOIST

The utility of the swinging jib crane



A STEAM-HYDRAULIC CRANE. MADE BY THE CRAIG RIDGWAY & SON CO., COATESVILLE, PA., U. S. A.

s limited by the fact that its fixed maximum radius leaves considerable areas outside of that uncovered. The remedy is to multiply the number of separate cranes, so that where the radius of one ends that of its neighbour shall meet it. This, however, is scarcely suitable for individual application, notwithstanding that it is the one generally adopted in Great Britain, and is, within reasonable limits, adaptable to the conditions of foundry work. It is just here, however, that the value of the system of overhead tracks comes in, on which light hoists are run along on single or double rails to serve the men over as much of the floor area as the tracks cover. These, in conjunction with the rapidly extending use of pneumatic hoists, constitute the greatest innovation of recent years next to the advent of the electric traveller. The system is very mobile, and highly developed in the United States, though still novel in British shops.

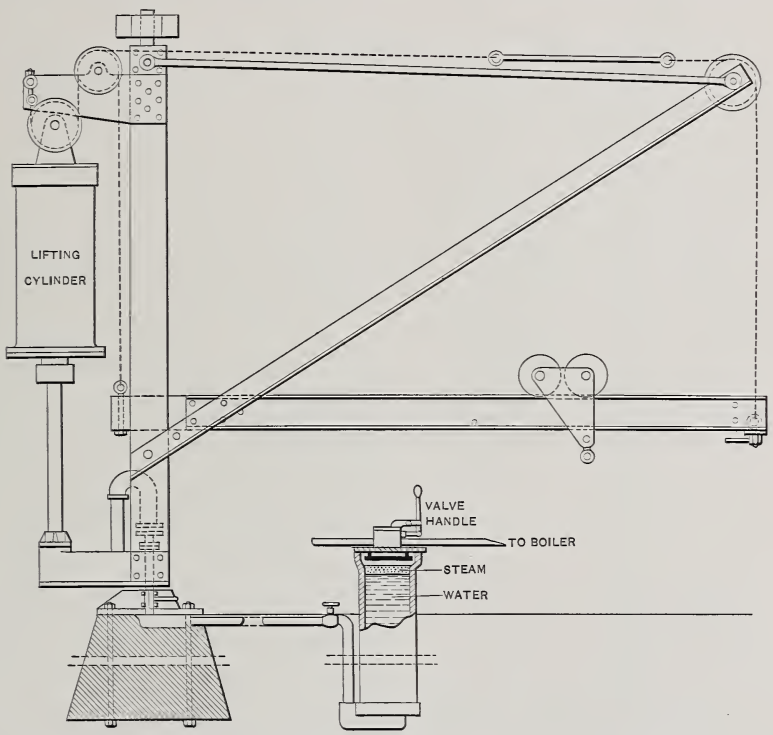
Though these two systems in themselves are quite distinct, yet they are usually mentally connected, as they are often in fact, because the chief value of the pneumatic hoists lies in the facility with which they can be run on overhead tracks, notwithstanding that they are also much employed now on jib cranes, in which application they possess many points of resemblance to the lighter kinds of hydraulic jib cranes. We must, therefore, give consideration to these new American systems of performing light hoisting and carrying in foundries, in which overhead tracks, hoists, and also jib cranes are actuated by compressed air, or by mixed systems, in which air, oil, water, steam operate in conjunction. The consideration of the jib cranes comes in naturally, because they are of special types developed by the experience gained on the hoists.

And first, in reference to the overhead track, there is nothing novel in the principle, for it was employed in machine shops and elsewhere long before it was applied to foundry service. But overhead tracks are now fitted up in such a complete manner as to constitute a new system. They are miniature suspended railways, fitted with turn tables and switches, movable points and safety locking devices to prevent the trolley from running off where changes of direction occur. The system bids fair to come into far more extensive use than

it is even at present. It is effecting a revolution in the methods of hoisting. For the fault of all the older methods of lifting in the foundry is want of mobility. Every crane, before the advent of the overhead traveller, was fixed, so that it was necessary to locate the work with reference to the lifting tackle, whereas in the new overhead system the tackle is brought to the work,—a most important distinction.

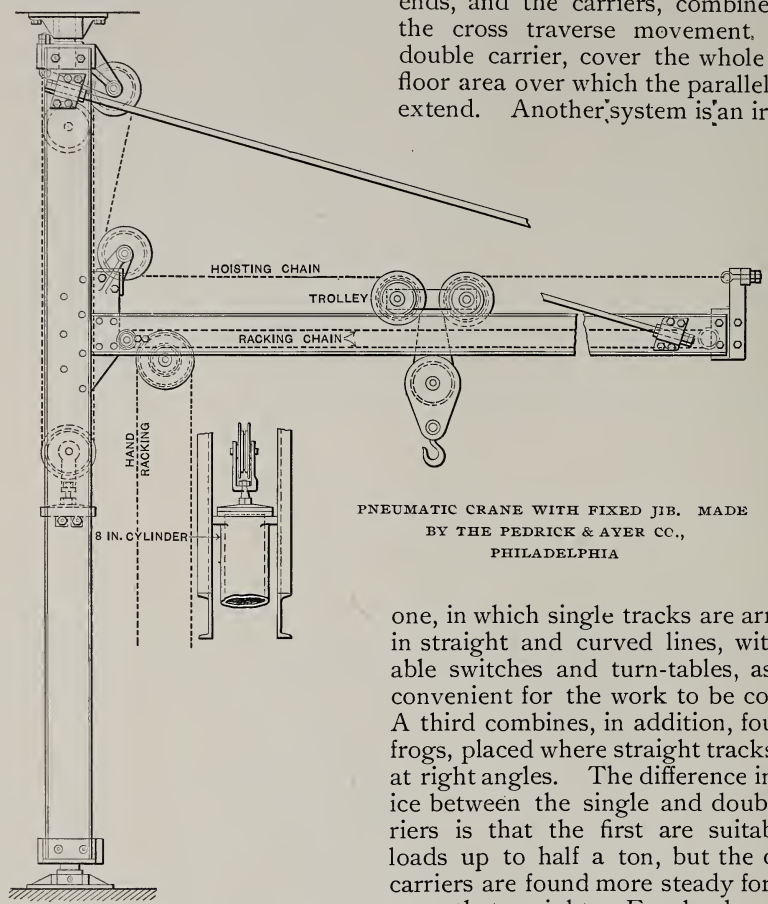
The fitting up of tracks is nearly independent of the kind of hoisting machinery used, and more than one method is adopted. The trolley and the track are integral parts in any one system, but any kind of suspended hoist can be hung from a trolley. Either pulley blocks or hoists can thus be utilised to travel along them and take away castings, lift copes, turn over boxes, bring materials, and carry metal from the cupola, which can be taken everywhere about the shop without changing hooks, since the tracks can be so multiplied in extent as to cover practically nearly al the floor area.

As the safety of the loads carried depends, first of all, on the stability of the tracks and the security of their switching arrangements, these must be well designed and carefully constructed. Tram rails of I section are used in some cases; in others, U sections, properly stiffened. The lower diagrams on page 233 show the hanger bolt used by the Brown Hoisting and Conveying Machine Company for attaching tram rails to beams. It is in the line of central stress, and is so well enclosed that it does not interfere with the use of large trolley wheels. The same type of bolt is used for wrought iron and cast iron hanger brackets, or for double joists. In all the various modifications of floors which exist in factories the bolt length is adapted to suit the conditions. Some of the illustrations accompanying this article show details of the track of this firm,—the turn-tables and the switches



BALANCED STEAM-HYDRAULIC CRANE. MADE BY THE CRAIG RIDGWAY & SON CO.

with automatic safety stops,—connection being made and broken by means of the dependent chains and handles. In some of these illustrations the system



PNEUMATIC CRANE WITH FIXED JIB. MADE BY THE PEDRICK & AYER CO., PHILADELPHIA

of hoisting by the Triplex spur gear blocks of the Yale and Towne Manufacturing Co., of Stamford, Conn., U. S. A., is shown. That on the left of page 228 represents one of one-ton capacity; one good feature of this is that the chain from the hoist block is led over a pulley a short distance away, so that the attendant is able to stand a little way off from the molten metal. This is really a short traveller carried on swivelling trolleys, capable of going round curves as well as along the straight tracks.

The Coburn trolley track is laid out in three systems. In one, parallel tracks are suspended from I beams, thus making a light structure. The longitudinal movements of the bridge, which is supported by the light truss framing at the ends, and the carriers, combined with the cross traverse movement of the double carrier, cover the whole of the floor area over which the parallel tracks extend. Another system is an irregular one, in which single tracks are arranged in straight and curved lines, with suitable switches and turn-tables, as most convenient for the work to be covered. A third combines, in addition, four-way frogs, placed where straight tracks cross at right angles. The difference in service between the single and double carriers is that the first are suitable for loads up to half a ton, but the double carriers are found more steady for loads over that weight. For loads of four tons, a quadruple carrier is used. The axles of the wheels run in roller bearings. This system is in use in foundries pouring as much as 35 tons of metal per day.

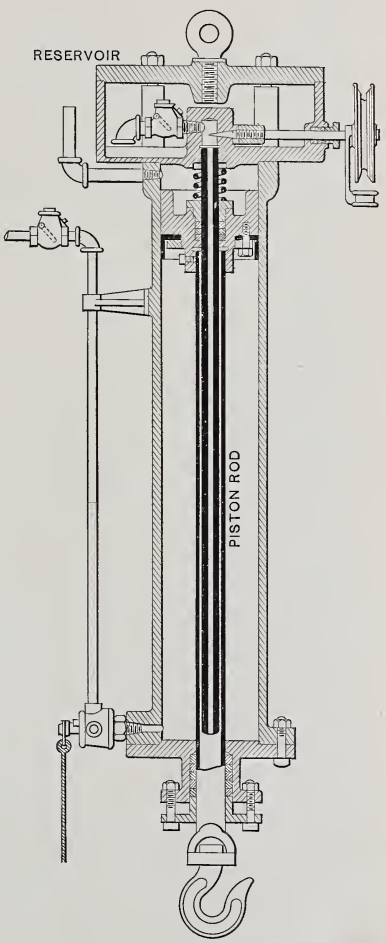
The foundry hoists used on tracks, and which are operated by compressed air, or in which compressed air plays the principal part, are light, being mostly below 5 or 6 tons capacity. In essential construction they are simplicity itself, since the lift is directly vertical, without a chain or a particle of gearing. The mounting of these is very diversified; the air is conveyed by means of flexible pipes, or by jointed

pipes. A long pipe is used, or detachable couplings. The couplings cause no difficulty, because the union of the two parts opens a check valve in the internally threaded end, which gives a free passage to the air. The severance of the coupling closes the check valve. In the double-valve type there are check valves in both male and female ends, so that when disconnected the air is retained in the hoist as well as in the hose pipe, and the hoist can be moved to another point with its load.

Because air is so highly compressible accidents are liable to happen to these hoists when a sudden change of load comes upon them. Hence the principle of governing them by a non-compressible fluid, as water or oil, has been adopted. Those which are not governed thus are generally controlled by automatic means. In the simple pneumatic system of the Pedrick & Ayer Company, of Philadelphia, the hoisting and lowering are effected by the direct movement of a piston and rod in a cylinder, operated by compressed air at 80 pounds pressure. The lifting capacity ranges from as low as 470 pounds with a 3-inch cylinder, to 14,000 pounds with a 16-inch cylinder. A four-foot lift is the standard or basis measurement, but the hoists are also made for five, six, seven, and eight-foot lifts, and for still others, if desired. The cylinders are set vertically, being hooked to any convenient point of attachment, the piston rod moving through the bottom cover.

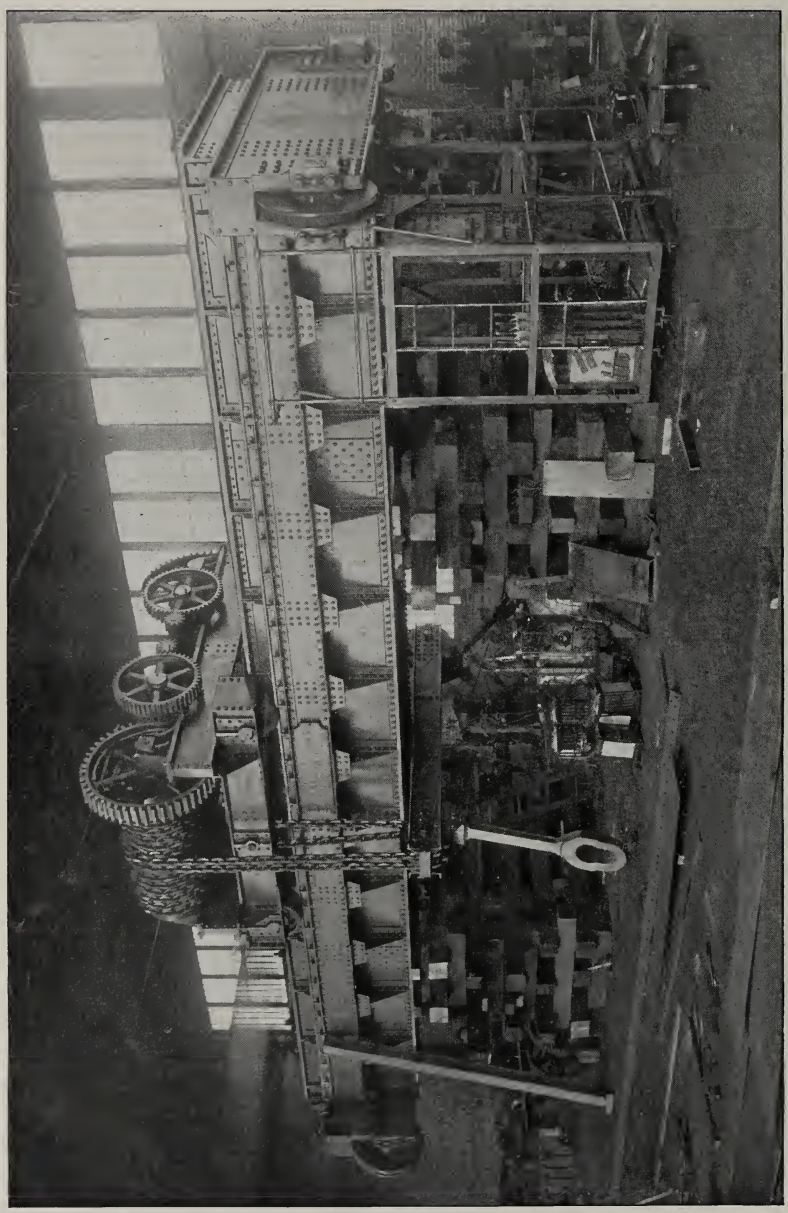
The difficulty due to the elasticity of air and to the variation of load is provided for by the use of automatic valves, supplementing the main valve, by which air is admitted or released, and which is operated by a dependent hand chain. Methods of application vary with the type of hoist used. In one instance an automatic self-closing valve shuts when the hand chain is released, whether the load is being raised or lowered. If it is desired to regulate the height of lift exactly, a loose collar is adjusted with a set screw in the piston rod to the height required. When the load is lifted to this height the valve closes and shuts off the supply of air. But should the air leak, the valve opens automatically and admits just as much as will suffice to keep the load suspended. A third type of valve maintains a variable load stationary, as when pouring metal. For use on horizontal hoists another special valve is designed to admit air on either side of the piston at will. The hoists are made to run along a single-rail track, and the piston gives motion to the hoisting pulleys.

The vertical air hoists are also applied



THE RIDGWAY OIL-GOVERNED AIR HOIST

to jib cranes, as well as to tracks, running along the horizontal members of the jib on a trolley, and supported on it by trunnions. The base pipe is brought to the top of the cylinder, and



ELECTRIC TRAVELLING CRANE MADE BY THE CASE MFG. COMPANY, COLUMBUS, OHIO, U.S.A.

the valves are either on the cylinder, and operated by a dependent chain, or they are fixed to the mast or pillar. In one direct-acting type the cylinder is placed between the uprights and actuates a chain at the end of the piston rod. The chain passes over a pulley at the top down to the jib pulley,—a very simple arrangement.

In the hydro-pneumatic governing type of hoist attached to jib cranes a small volume of compressed air acting on a large volume of water or oil in a closed cylinder operates the plunger in another cylinder. The first, or reservoir cylinder, is connected to the hoisting cylinder, set within the mast, by means of a pipe, the passage of the fluid through which is controlled by a valve. On the admittance of water from the reservoir to the lower part of the hoisting cylinder the plunger is lifted, carrying up the jib bodily. A trolley runs along the jib to the radius required. The jib end runs on the mast by four friction wheels, two at the front and two at the back. Loads of from one to ten tons can be lifted thus. In another jib crane the pneumatic cylinder acts upon a column of water which operates the hydraulic cylinder situated between the H sections of the post or mast, and so actuates the chain, the jib being a fixture. Racking of the trolley along the horizontal jib is done by a dependent racking chain and wheels in the usual way.

The air hoists of the Craig Ridgway & Son Co., of Coatesville, Pa., U.S.A., are oil governed; that is, the action of the air is controlled by oil in a reservoir and hollow piston rod, the ingress and egress of the oil into the latter being regulated by valves. A hollow rod passes through the hollow piston rod, (see page 239), leaving a clearance space between the two. The rod is fastened into a reservoir on top of the hoist cylinder. The piston packing makes a close sliding fit over the hollow rod. A valve, operated by a dependent chain, regulates the passage of oil between the receiver and the hollow piston rod. The rod is first filled with oil when the piston is at its lowest end, the oil rising above the valve. Bringing a head of air into the cylinder and opening the valve permits the oil to escape into the reservoir and the piston ascends. When the piston descends under the load the oil returns into the rod. The degree to which the valve is opened regulates the rate of movement. It may be very quick, or so slow as to be almost imperceptible.

A type of crane of which a great number are in use in the United States is the balanced steam-hydraulic crane of this firm. The distinguishing features of this are the use of steam to produce pressure on the water, the moving of the cylinder instead of the piston and rod, the vertical movement of the jib, and the balancing of the jib and load by the water cylinder, all combining to produce a perfectly smooth motion. In this design there are two cylinders, one that acts as a water reservoir, and another that is operated by the water pressure. The reservoir cylinder is partially filled with water. Steam is admitted above, and is prevented from mixing with the water below by a cushion of air intervening, and by a baffle plate interposed between the steam and the air. The steam supply is controlled by a slide valve, and its pressure is transmitted through the air to the water below. The water, under pressure, is transmitted through pipes to the piston rod of the lifting cylinder. This rod is hollow, and the pressure produces the descent of the lifting cylinder over its piston. Chains from the top end of the cylinder pass over pulleys and down to the jib, lifting it in this case with the same amount of vertical traverse as that of the cylinder. In another modification the chains pass around wheels at the head of the cylinder, their ends being attached to brackets. Instead of the jib having the same movement of the cylinder as in the design just named, it has double as much, so giving the advantage of high lift. To release and lower the jib and load the steam is exhausted by the moving of the valve, when the water flows back from the hoisting cylinder to the reservoir, allowing the cylinder to rise and the jib to lower. The steam pressures used are

those ordinarily employed in a factory, or from 60 to 100 pounds. This, for heavy loads, involves the employment of a large cylinder, which has a rather unsightly appearance. But as this fulfills the function of balance to the jib, it becomes no more objectionable than the balance behind an ordinary hand crane.

This description relates to the general or standard type of crane, but several modified forms are built, adapted to the requirements of different shops. The water does not waste in this system, but remains in service for an indefinite period. Anti-freezing mixtures of water and glycerine can be used, so that one objection to the employment of hydraulic cranes in cold localities does not exist with them.

It should now be clear that steam is of little value as a motive force when used directly for the hoisting machinery of a foundry. It is better converted into electric, hydraulic, or pneumatic energy, each of which, of course, requires a plant. But at least two of these agencies are well-nigh indispensable in any modern foundry of large size in which the aim is to secure the most economical results in working. When contemplating laying down a plant, it must not be forgotten that there is other power driving in the foundry besides the cranes. There are the various grinding mills, the blower, the tumbling barrels, sand sifters, cupola hoists, and so forth, all of which, except the last, are usually belt-driven from a steam-engine and shafting. Hoisting by compressed air is also adapted for foundry use, because an air compressor plant is valuable for other work besides hoisting.

From this point of view it is advantageous to have one well-equipped power plant laid down in a works. Instead of small boilers, located in half a dozen places, with as many attendants, the single power plant, comprising as many boilers of large dimensions as are likely to be wanted for the requirements of the coming years, are set in one spot, and the power thus generated is always available for steam, hydraulic, electric, and air-operated cranes and machines, and for lighting. The growth of these plants in recent years is largely due to the increasing demands which are made upon the last three modes of transmission, and for light, each of which can be taken throughout a large works much better than steam. Many of the older firms who find themselves committed to steam only are unable to avail themselves of the most economical and adaptable hoisting machinery. In many instances these would be well advised to lay down an ample power plant, the first cost of which would, of course, be heavy, but which would, in the end, pay for itself by great economies resulting from the selection of the best methods of operating not only the hoisting, but the other machinery in the shops, and for lighting them with incandescent and arc lamps.

ECONOMIES IN MACHINE-SHOP WORK

JIGS AND SPECIAL TOOLS. SPEEDS AND FEEDS

By Oberlin Smith

THERE are in modern machine shops two general classes of working economies adaptable to two general classes of shops. One of these is the manufacturing shop, pure and simple, or one which seeks to become so. In such a shop a comparatively few kinds of articles are made and these are produced in very large quantities,—all of a given kind being exactly alike and having their parts interchangeable. Specimens of such work are mowing machines, small printing presses, small steam engines, and, more typically of the kind of work in question, typewriters, sewing machines, and pistols.

About work of this kind there is little question as to methods. In the United States there have been developed during the last twenty or thirty years a breed of men who are not only inventors, but skillful mechanics and works managers, it usually being necessary to combine these three characteristics in one man to make him thoroughly competent to organise and operate a factory for producing good work on the "duplicate system." Not only must such a man know how to make a typewriter or sewing machine, but he must know how to deal with each individual piece separately, making it a complete manufactured article in itself. He must know how not to try to make the machine complete, except as a matter of the final assembling of a group of perfectly fitting (not fitted) parts.

He must, first of all, know whether the perfected model, or alleged perfected model, which is brought to him to manufacture is so designed as not only to work well and perform its functions with accuracy and durability, comparing favourably with other machines of the kind on the market, but whether such machine has been reduced to its simplest form, in view of economy in manufacturing. Not only must the form be simple in regard to having as few pieces as possible, but each piece must be of such a simple shape that it can easily be manufactured with the ordinary machine tools available, supplemented by such special "tools and fixtures" as can be made to form a part of the development of the desired manufacturing operations. This expert, together with such assistant experts as he may have the ability to properly select, must make careful study of each piece of the article to be manufactured and of each operation on each piece. They must further have the ability to design and make drawings of such gauges, templets, jigs, and cradles as are necessary for each of the operations in question.

When all these expensive tools are completed, with test gauges for keeping them of the right size and shape, master-gauges must be provided (and should be carefully locked up in a fireproof safe) by which to test the test gauges. The manufacture of the article then becomes ready to be carried on, but it must be under the most rigid system in regard to speeds and feeds of tools, and in regard to the accumulating of material and handling of the product as fast as it is completed, so as to keep the right quantities of each piece made up at the proper time and so as to keep things from getting mixed up, as they often are in ordinary machine shops. The

assembling must then go forward on the piece-meal system, certain groups of pieces being put together and tested for fit and freedom of running, after which the various groups are finally brought together into a completed machine, another final test of the whole mechanism being duly made.

The above is but a cursory glance at the system of cheaply making small machinery on the interchangeable system, it standing to reason that separate pieces made and tested by gauges in the way above indicated will go together without fitting, using the word fitting in the sense of filing or scraping the respective surfaces until the pieces harmonise. Of course, if any piece will thus go together in conjunction with the particular piece of another kind which happens to be brought to it in the assembling process, it would, when thus assembled, be capable of being reassembled with any other individual pieces than the one with which it happens first to come into conjunction.

It seems needless to say that if a system, like the one just indicated, is properly carried out, the manufacture of the product has been brought to the extreme lowest point in the matter of cost; and it is well known that such methods have brought within reach of the masses of the population of the world conveniences, and what are now considered necessities, of various sorts which, if made in the old-fashioned way, would cost from ten to one hundred fold more than they do now.

The other general class of machine shops referred to in the first paragraph often work entirely upon the old-fashioned "jobbing" plan, that is, with each article made by itself, with ordinary tools and ordinary workmen. Of late years, however, shops of this kind have many aspirations toward "manufacturing" their products rather than merely "making" them, as heretofore —and therein often lies the whole difference between profit and loss.

This system can often be carried out to a limited extent only. In the shops in question I do not include the merely "jobbing" shop which deals wholly with repair work, or perhaps also with some little new work for inventors and others who never want but one article of the kind. I rather have in mind the large majority of the regular machine shops which build such things as machine tools, printing-presses, steam-engines, presses and dies for sheet metals, etc.

Many of these shops build for their product such a large number of kinds of articles and so few of a kind in each batch, if indeed they make batches at all, that it is not practicable to go very far in the way of making jigs and other special tools. This is not only on account of the cost of such tools, but also because of the lack of having carefully standardised the articles forming the products on which to use them. In such cases there is much danger that the jigs will have but a short life, being soon thrown out of use and becoming absolutely worthless except as scrap-iron, through some change in design, which may be perhaps quite trivial, in the article for which they were prepared.

In starting each new construction or improving old constructions the question whether or not to make jigs (I use the word jigs as a convenient term to cover several kinds of special tools usually consisting of gauges, templets, jigs and cradles) becomes one of the most vital importance in relation to the making or losing of money in the ordinary machine shops of the semi-manufacturing class which are here under consideration. It often happens that a too enthusiastic manager, who knows the enormous saving that can be made in a large output cost of some single piece by the use of proper jigs, and who, perhaps, is familiar with some of the methods employed in a wholly manufacturing shop such as has been mentioned in the earlier paragraphs, will look into the making of some article which has lately arrived at the stage of being run through the shops in batches of ten at a time, and will figure out how these can be produced for half the money by building a set of jigs, etc. His judgment in the matter may not be good; the time may not have come when it

will pay to make these expensive tools for the particular article in question. There may be various other articles for which it surely would pay to make jigs, and there may be still others about which such action is doubtful. In some cases boards of directors who may really have very little practical knowledge of the question in hand, but whose imagination has been fired by the wonderful savings made in some neighbouring factory, will vote that jigs immediately be made for such and such an article, and that its production must be vastly cheapened.

I have in mind a case of this kind, where a manager was ordered to make a set of jigs for building a medium-sized machine, limiting his expenditure to an amount which was not one-third enough to cover their cost. The job, moreover, was ordered to be finished by a special time which was not one-quarter far enough in the future to allow the completion of the work. Furthermore, the manager knew that the machine in question was not ready for being made in this way, as it was not yet standardised and was subject to several inevitable alterations. The manager grinned, but was not absolutely obedient.

In general, certain rules may be formulated for this vitally important matter of earning money in the production of the large class of machinery which is being semi-made and semi-manufactured, so to speak, in many shops.

First, do not make a full set of jigs for manufacturing all the parts of a machine unless that machine is fully standardised. This standardising should be on a basis of having gotten the machine practically perfect by long operative experience in the hands of customers, by careful comparison with competitors' machines of like character, by experimental shop trials, and by careful study as to the simplest, strongest and most beautiful form of design.

Second, delay the making of such jigs for the newly standardised machine until there is a reasonable certainty that it can be made in batches of, preferably, not less than ten pieces of a kind at one time, and this without danger of the batches being broken into when partly completed, as is so apt to be the case. It may, under some conditions, with certain large pieces, pay to make and use jigs for a smaller batch than ten, possibly as low as five; but, on the other hand, it is better to have considerably more than ten if practicable. This can frequently be done with the smaller pieces of a machine, making perhaps 50 or 100 at a time, while the larger pieces may be run through in smaller batches.

It is obvious that the principal reason why the pieces made in a small batch are vastly more expensive than those made in a large one is not so much that there are serious differences of speed in performing the actual operations upon the piece in question, but that a constant time item must be added to any sized batch, to cover what is technically termed rigging-up and unrigging. Thus it may take anywhere from five minutes to five hours to rig up a jig and its appurtenances, together with the machine in which it is to be used, including the finding of all parts, the testing of them for correctness, such adjusting as may be necessary, etc., followed at the end by unrigging and putting everything back in place.

An instance of this, especially pertinent, might occur in the case of jigs for a heavy casting used in a large boring-mill, where, perhaps, the mill itself has to be cleaned off, the speed and feeds changed, various heavy parts adjusted to position, and the boring and facing tools carefully set. Another instance is seen in arranging a turret lathe for making some particular kind of bolt, or stud, or collared shaft. In this case extreme accuracy is necessary in the adjustment of the cutting tools, in order that proper sizes may be produced upon the work both in diameters and lengths.

Instances of the opposite kind, with a small time constant, may be seen in the case of a small, flat jig which simply lies upon the work, perhaps being fastened by thumb-screws or by a simple cam lever, the work itself lying upon the table of an ordinary drill-press. If we assume that this drill-press is one which is always standing ready for use

and which does not have an adjustable table, it is evident that the rigging-up and unrigging may be done in a very few minutes, especially if but one ordinary drill is to be used, which can be called quickly from the tool room, or which accompanies the jig.

It is obvious, in any case, that if the rigging-up and unrigging takes a good deal longer than does the work upon one piece, it would be necessary to have several pieces in a batch to make this method of working pay—unless, indeed, the use of the special tools in question should so vastly quicken the speed and accuracy of the work that the total time occupied would be less than if the piece were made by hand. It is well to keep in mind these various phases of the matter when calculating whether it will or will not pay to use a set of jigs.

It is hardly necessary to say that in designing a machine as many of the pieces should be made identical as possible, sometimes even by throwing them slightly out of the correct theoretical proportion. For instance, a number of bolts, pins, washers, or small shafts may sometimes be made all alike, when absolutely correct design would show that some of them should be a little smaller. Within reasonable limits, however, it pays to thus reduce the work to as few units as possible, that the special tools to make them with may be few in quantity while the batches of work may be full to overflowing with the duplicate pieces, which are cheap in proportion as they are numerous.

A careful study and revision of the details of all of a certain group of somewhat similar machines will often develop opportunities for making duplicate pieces which will interchange among the different machines, thus still more facilitating the operation of making special tools and running through them large batches of work.

Besides unifying as much as possible certain different machines, it is an important point, in any shop, to have certain general standards which will do for all machines. The most obvious of these are screw-threads for bolts and nuts. Beyond these it is well to have shop standards for various kinds of machine screws, for set-screw heads, for washers, both thick and thin, for keys, for feathers, for dowels, for collars, for shaft diameters (as a matter of course), and for various other things which it is unnecessary to mention here.

It is, of course, taken for granted that such tools as are necessary should be provided for all these general standards. These, obviously, are different in their nature from special tools proper, such as jigs, etc., but may be considered as special general tools.

In general, great care must be taken not to overdo the making of jigs, while, on the other hand, still more care must be taken not to neglect the making of them in cases where they will pay. A careful manager, however, will soon learn, by going gradually into schemes of this kind, how far he can safely proceed upon other machines after getting experience with the first one. But the interesting fact must constantly be kept in view that no matter how well a set of jigs may work, and how much money they may save each time they are used, their inventory value is necessarily evanescent, as it may utterly disappear, or rather be dissolved into the price of scrap-iron, should a serious change in the design of the machine to which they pertain take place, or should the demand for it cease in the market. The vital points to be considered, therefore, are:—1st, what is the probable number of times the proposed set of jigs will be used? and, 2d, will the total cost of such jigs be considerably less than the net saving made by them during such given number of times using?

The above paragraphs are intended to give some information regarding one way of saving money in the ordinary modern machine shop. Aside from this matter of special tools, there are not very many big economies available, assuming that a shop is well equipped with modern power-generating and power-transmitting apparatus, good machine tools, suitable cranes and other hoisting devices, proper light, heat, and ventilation, etc.—assuming also, of course, that the working force is prop-

erly organised, and so managed as to do a full day's work every day.

There are two points where some economy can be attained in almost every shop. These are in the matter of speeds and feeds. The universal tendency of workmen, even though thoroughly conscientious and industrious, seems to be toward running slower cutting speeds than necessary. The highest speed for cutting a given material with given tools, which, of course, should be of the best possible quality, is one that can be kept up only by constant watchfulness and by a careful system of instructions to the workman as to what speeds to use for each kind of material and for given dimensions.

The matter of feeds is likewise one of great importance and can be kept up only, as mentioned in the case of speeds, by constant watchfulness. The tendency of workmen is to feed too slowly, taking, in consequence, too small a chip. A proper width of feed obviously depends upon the depth of cut, the product of the two giving the greatest suitable cross-section of metal that may be removed under the particular circumstances. The whole question of having maximum cutting speeds, depth of cuts, and width of cuts is one for which it will pay any shop to organise special rules and over which it will pay to exert special watchfulness. More money is lost than is generally supposed by neglecting these matters and leaving them wholly to the judgment of the workmen, who do not always seem to realise their importance.

THE DEVELOPMENT OF FLY-WHEELS

By Charles H. Benjamin

PROBABLY the fly-wheel germinated in the fertile brain of James Watt, as did the governor, the condenser, and many another detail of the modern steam-engine. In the earlier designs of pumping engines there was no crank, no fly-wheel, only the cumbrous walking-beam, with the piston at one end and the pump rod at the other. But as Watt developed the idea of using steam expansively and of using it in both ends of the cylinder, the necessity of some storage of energy became apparent, even in the slow-moving engine of that day. Accordingly, about the year 1780 we find the double-acting steam-engine with crank and fly-wheel making its appearance. The earlier wheels ran at such absurdly low speeds that the element of danger was almost entirely absent, and if a fly-wheel ever failed, it was not on account of centrifugal force.

FIG. I.—A PULLEY WITH A BROKEN ARM, ILLUSTRATING INITIAL STRAIN

As in the earlier boilers, working with steam at atmospheric pressure, explosions were unknown and safety valves yet to be invented, so in the engines of the last century the fly-wheel had no thought of flight as it soberly made its ten or twelve revolutions per minute. The nineteenth century has changed all that. The horse trots in 2.04 instead of 2.40, the bicycle and the automobile go a mile a minute, the Atlantic "greyhound" and the Pacific "flyer" continue to cut records, while financial, social and mechanical safety valves are all blowing off at high pressure.

Within twenty-five years boiler pressures have crept up from 70 to 250 pounds and piston speeds from 300 to 800 feet per minute, while improvements in strength of material and security of design have hardly kept the pace; boilers and fly-wheels are exploding all around with lamentable regularity. It is of no use to cry "halt;" the modern man will not halt; speed and pressure will continue to increase, and measures must be taken to make the increase safe. The introduction of various forms of safety boilers for high pressures and the more stringent laws with regard to license and inspection of steam boilers will probably lessen the danger there. A fly-wheel is just as dangerous as a boiler, and

should be subject to inspection in like manner.

The demand for a high rotative speed in engines used for electric power and lighting is responsible for many fly-wheel accidents, and it is also probable that many rolling-mill engines are now turning faster than their builders intended. The designs of many of the older wheels now in use are entirely

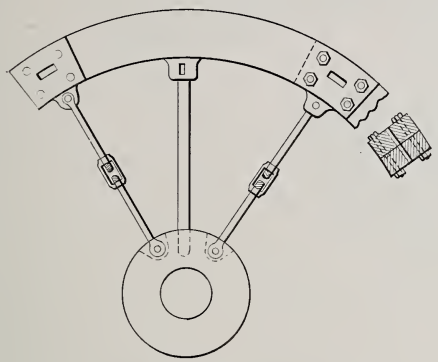


FIG. 2—AN OBJECTIONABLE RIM JOINT

wrong, especially in the feature of rim joints, and while the wheels were comparatively harmless at low speeds, they are now perilously near the bursting limit. Some years ago the writer had occasion to investigate a large wheel of the rolling-mill type. He found the strength of the joints less than one-third that of the solid rim, and the factor of safety at the given speed about two. The old wheel has since ended its life, and, fortunately, without killing any one.

Both builder and owner are sometimes aware of the narrow margin of safety, and, when an accident happens, are anxious to prevent an investigation. The time to investigate a fly-wheel is during its lifetime, and the one to investigate it is a trained inspector, who can pronounce intelligently on its safety or condemn it if dangerous.

Fly-wheels may be classified as follows, according to the method of construction:—

1. Solid cast iron rim and arms.
2. Sectional or jointed rim, bolted to arms.
3. Cast iron rim with steel spokes.
4. Steel plate wheels with web instead of arms.
5. Wooden wheels, built up with glue, and nails, or pegs.

1.—The solid wheels are usually less than ten feet in diameter, as wheels larger than this cannot be easily transported in one piece. This type of wheel is peculiarly subject to cooling strains, which throw an initial tension on the arms. A cast iron pulley which was broken by the writer in the testing machine shows this clearly. When the pulley was subjected to a twisting moment one of the arms broke near the hub, the two parts separating nearly an eighth of an inch, as shown in Fig. 1, indicating considerable initial strain.

Solid wheels are also apt to have weak, spongy iron at the junction of rim and arm. However, if the wheel is properly proportioned and is cast by a foundryman who understands his business, it is probably the safest of all cast iron wheels. The writer has attended the obsequies of several wheels of this class, where, with one or two exceptions, the breaks showed clean metal and were due solely to excessive speed.

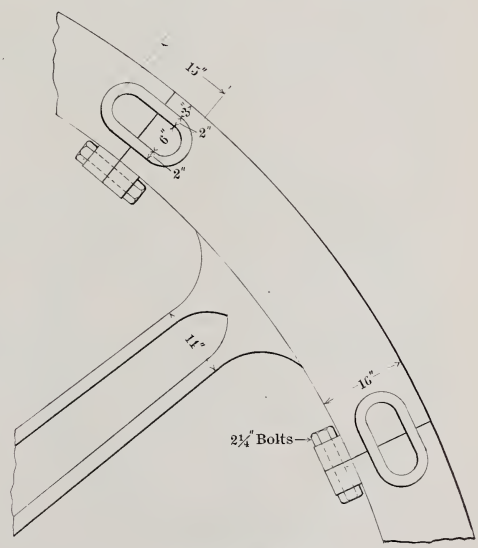


FIG. 3—ANOTHER UNSAFE JOINT

The tension on the rim of a cast iron wheel due to centrifugal force is ap-

proximately $v^2 \div 10$ pounds per square inch, where v is the speed of rim in feet per second. Using 18,000 pounds per square inch as the tensile strength of cast iron, this formula gives the bursting speed of the rim as about 425 feet per second, or nearly five miles per minute. Numerous experiments made by the writer in testing to destruction model wheels from 15 to 24 inches in diameter, show a bursting speed of from 375 to 430 feet per second. Wheels with thin rims or an insufficient number of arms will burst at a less speed than this, on account of bending of the rim between the arms.

FIG. 4.—A FRACTURE THROUGH LINK RECESSES

FIG. 5.—A WHEEL WHICH FAILED AT THE JOINTS

2.—Wheels larger than ten feet in diameter are usually cast in two or more parts, and if more than sixteen feet in diameter, the rim is generally in segments, one segment to each arm. The arms may be cast or bolted to the segments, according to the size and design of the wheel. The form of joint to be used depends entirely on the shape of the cross section of the rim, and this, in turn, on the use to be made of the wheel. Wheels which are to serve merely as regulators and which do not carry belts, can have narrow and deep rims, either solid or hollow, and of the best shape to resist bending.

Each section of rim between two adjacent arms of a fly-wheel, when turning fast, is in the condition of a beam fixed at the ends and uniformly loaded, the bending action being most severe midway between the arms. When, as is usually the case, the joints of the rim come at these points of greatest bending, they are a decided source of weakness. Some of the earlier forms of wheel are particularly weak just here. Fig. 2 shows the details of a rim joint in a rolling-mill wheel which recently gave up the ghost. It will be noticed that halving at the joint reduces the strength 50 per cent. at one stroke, while the bolts and cotter cut into the remainder seriously. Tension rods connected each joint with the hub to counteract the bending action, but no one knows how tight they were.

In Fig. 3 we may see the details of a

rim joint on the rolling-mill wheel referred to in the first part of this article. This wheel had been unsafe for some time, and finally failed on account of a sudden stoppage of the rolls to which it was directly connected.

Fig. 4 shows the fractured joints of a 24-inch model wheel of this class, which burst at a rim speed of 320 feet per second, the rim breaking across near the joint where weakened by the link recesses. The tensile strength of the links was a little more than three-fourths that of the solid rim. This wheel, at the usual maximum rim speed of 100 feet per second, would have a factor of safety of ten.

Fig. 5 is from a photograph of a 24-inch wheel modeled from the drawings of a leading firm of engine builders. The original was 20 feet in diameter, and was intended for a 24-inch shaft. The model burst at about 2500 revolutions per minute, or a rim speed of about 260 feet per second. The I-shaped prisoners were uninjured, the fracture being in the cast iron at the joints.

The three bolts joining each arm to the hub were modeled exactly to scale from the drawing; it is interesting to note that after the failure of the rim each arm pulled out radially from between the hub flanges, cutting off the bolts as cleanly as if done with shears.

On the whole, the rolling mill wheel does not offer a very serious problem, and the joints may easily be from two-thirds to three-fourths as strong as the solid rim. John Fritz, of the Bethlehem Steel Company, has probably set the high-water mark of this form of construction in the wheels described by him in this magazine for June, 1899.

Fly-wheels which are also to be used as belt wheels present a more difficult problem. The rims of such wheels must be of a width slightly greater than that of the belt or belts to be carried, and consequently must be comparatively thin and of a shape ill adapted to withstand bending. It is difficult to join the segments of such a rim to one another and to the arms without weakening the structure. Formerly the rim segments were joined midway between the arms by means of internal flanges and bolts, thus putting extra weight of metal and a weak joint at the most dangerous section. A joint flanged and bolted in this way under the most favourable conditions has only about one quarter of the strength of the solid rim and is weak against bending. This may be better

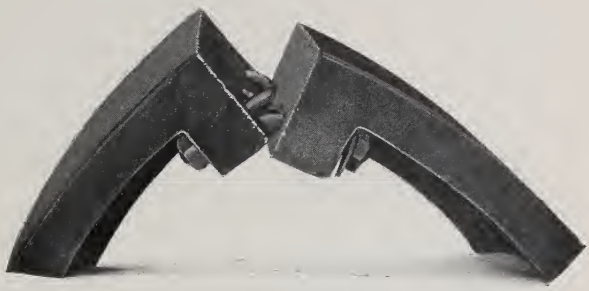


FIG. 6.—AN OPENED JOINT WITH BOLTS STRETCHED AND BENT

FIG. 7.—JOINTS NEAR THE ARMS FOR GREATER STRENGTH

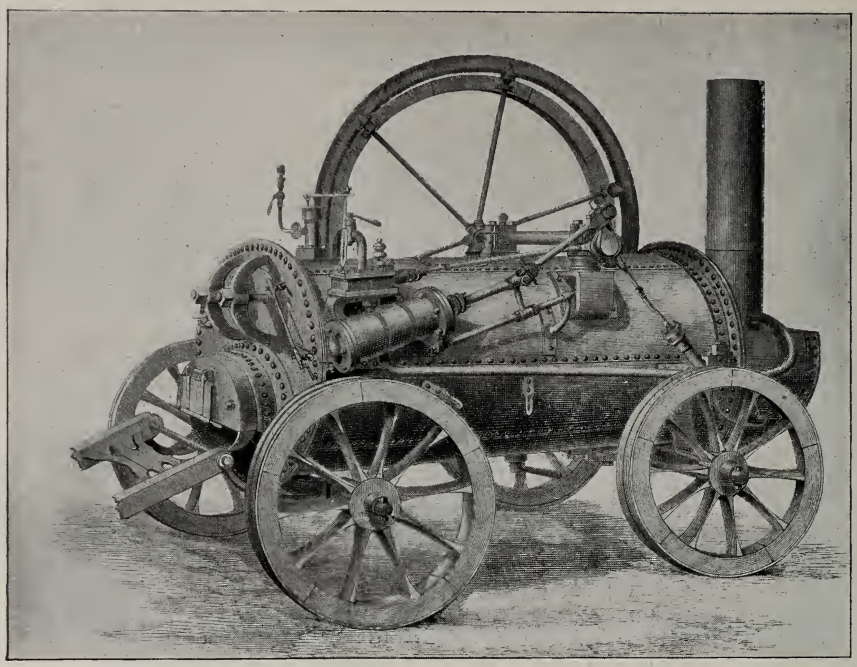


FIG. 9.—AN EARLY FORM OF PORTABLE ENGINE HAVING A FLY-WHEEL WITH CAST IRON RIM AND HUB AND WROUGHT IRON SPOKES

understood by reference to Fig. 6, which shows the opening of the joint and the stretching and bending of the bolts under the action of the centrifugal force, the inner edge of the flange being the fulcrum. Twenty-four-inch model wheels of this character burst at a rim speed of about 190 feet per second, showing a strength about one-fifth that of the solid wheels. With a belt speed of 6000 feet per minute, such a wheel would have a factor of safety of a little over three.

FIG. 10.—A FLY-WHEEL WITH SPOKES IN PAIRS FORMING U-SHAPED LOOPS

Mr James B. Stanwood has proposed putting such joints near the arms at the points of inflection of the rim. The writer has constructed several model wheels on this design, as shown in Fig. 7, and expects to test them to destruction, but will venture no predictions in regard to them.

Fig. 8 shows the more modern way of designing the arm and rim joints of large belt-fly-wheels, as practiced by some leading engine builders. The

rim joint is in this brought directly over the arm, and the effect of the extra weight at this point will be to stretch the arm more and relieve, to some extent, the bending of the rim. At its best, however, the bolted flange-joint can have but a fraction of the strength of the solid rim.

Another source of weakness in wide belt-fly-wheels is found in the great width of overhang beyond the arms. The outer edges of the rim, being unrestrained, stretch more under the action of the centrifugal force than the part which is held in by the arms, and the result is a bending of the rim such as would give to it an hour-glass form. This action has been sufficient, in one or two cases, to crack the flanges which run parallel to the shaft inside the rim and to seriously cripple the wheel. Probably the best solution of this difficulty is either to have two independent wheels side by side, or to use two parallel sets of arms, as in cable drums.

3.—The fact that a considerable part of the stress in a fly-wheel rim at high speed is due to bending between the arms has suggested the use of a large number of light arms at short intervals. As such a construction would make cast iron arms too small to cast well, steel spokes, similar to those of a bicycle wheel, have been substituted. The rim, in such a case, may be solid or may be bolted or linked together by any of the methods already indicated. The steel spokes will be attached to flanges or lugs in the rim by screw threads and nuts, in such a manner that they may be easily adjusted for tightness.

Perhaps the earliest example of a fly-wheel with wrought spokes is the one shown in this magazine in December, 1895, attached to a Cambridge portable engine.* The date given is 1843, and the wheel is shown (see Fig. 9) as having a solid cast iron rim and hub, with the spokes apparently cast in. A wooden rim for the belt is shown as attached to the spokes at one side and just inside the cast rim. Mr. E. S. Cobb, of San Francisco, has designed a trussed steel wheel of this type which has been adapted to fly-wheels and also to Pelton water-wheels. There are radial steel spokes which support the weight of the rim and resist the centrifugal force, and,

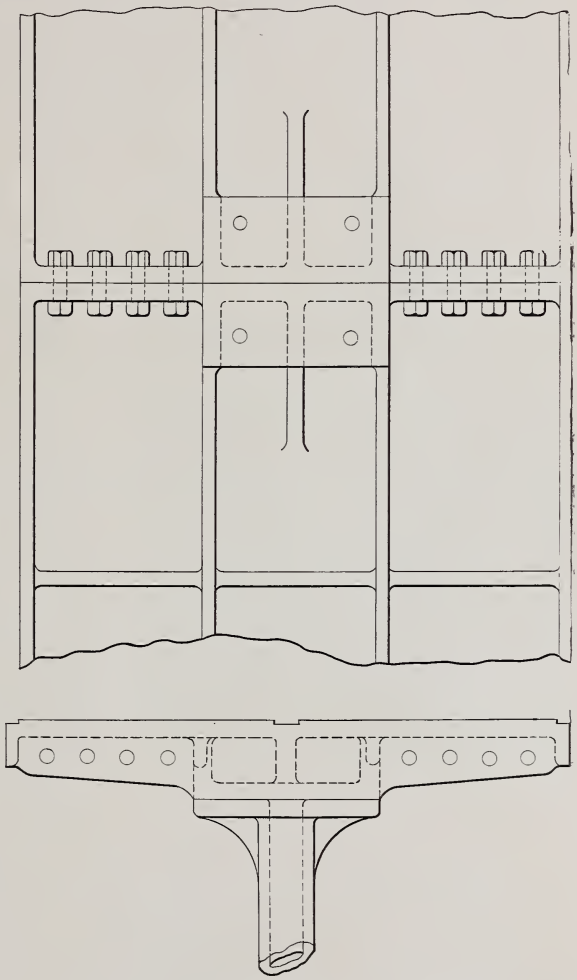


FIG. 8. A MODERN ARM AND RIM JOINT DESIGN

* The illustration referred to is reproduced on the opposite page.—THE EDITOR.

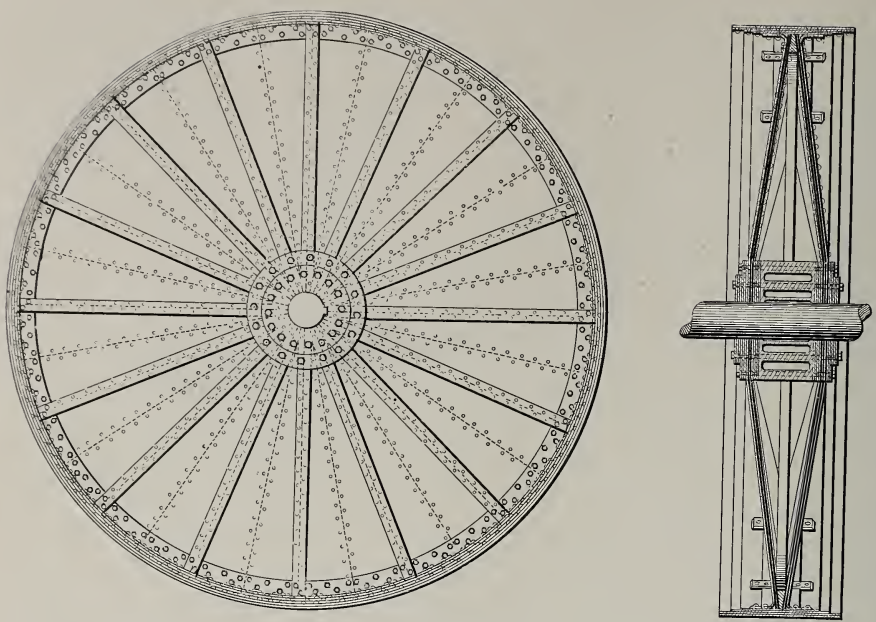


FIG. 11.—A 20-FOOT BUILT-UP STEEL BELT WHEEL IN THE POWER HOUSE OF THE ALBANY RAILWAY COMPANY, ALBANY, N. Y., U. S. A.

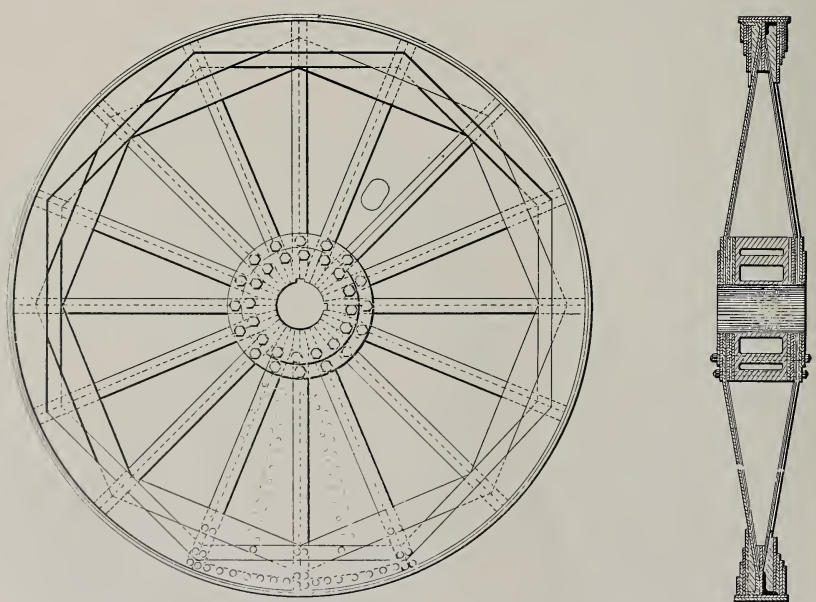


FIG. 12.—ANOTHER FORM OF BUILT-UP WHEEL

in addition to these, steel truss rods, tangent to the hub.

Fig. 10 is from a photograph of one of two 24-inch model wheels constructed by Mr. Archibald Sharp, of London, and sent to the writer to be tested. In this wheel the rim is solid and of I-shape, which gives great rigidity. There are pairs of spokes, each pair forming a continuous U-shaped loop which passes around a spiral groove in the hub and fastens to the rim at each end with nuts and checks. The spokes thus hold the hub by friction alone, and may be easily adjusted for even tension and true running. This wheel promises well, but at the present writing has not been tested. It may not be amiss to say here that there is now a permanent apparatus for testing small wheels to destruction at the laboratories of the Case School of Applied Science, at Cleveland, Ohio, U. S. A., capable of taking wheels up to 5 inches in width and 24 inches diameter, with 1 7-16 shaft, and the writer would be glad to receive models at any time for this purpose. Wheels with numerous steel spokes are undoubtedly stronger and safer than those with cast iron spokes, but there still remains the fact that the tensile strength of cast iron is only about 18,000 pounds per square inch, and that rim joints are never as strong as the solid metal. The old wheel shown in Fig. 2 had wrought iron spokes, one at the centre of each rim segment, fastened with a cotter, and one lighter rod at each rim joint, fitted with a turnbuckle to secure even tension. But spokes cannot make safe such a rim joint as is there shown. The steel rim must come, sooner or later.

4.—Wheels of steel plate and structural steel have often been proposed as the best solution of the difficulty, and a few have been built. In the issue of this magazine for August, 1896, several structural wheels of neat design were shown and described. The illustrations have been reproduced in Figs. 11 and 12. All things considered, the steel wheel is probably the strongest wheel yet built, but in many cases the cost would be prohibitive. Where the wheel is to be used as a fly-wheel only, additional weight of rim may be secured by building the plate rim of trough or spool shape and winding on the necessary weight of steel wire. At high speed the wire will stretch and carry its own centrifugal tension without affecting the rest of the wheel.

5.—One who has not given the subject much thought will be inclined to smile at the idea of substituting wood

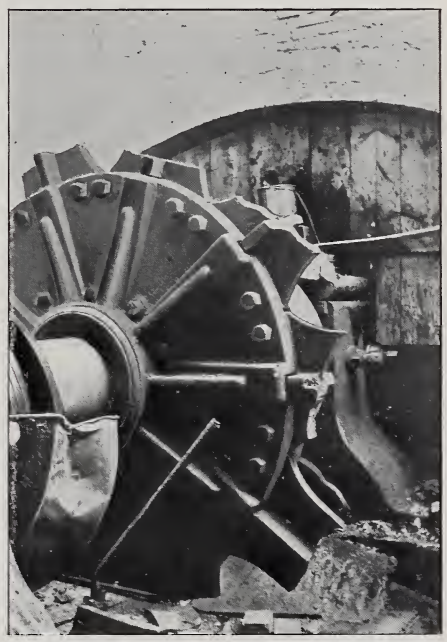


FIG. 13.—A RESULT OF BLOCKING THE GOVERNOR

for cast iron in fly-wheel construction. In itself, however, wood is the better material. The limit of speed for cast iron, about 425 feet per second, is calculated on a basis of 18,000 pounds per square inch tensile strength and a density of 450 pounds per cubic foot. If we assume 5000 pounds per square inch and 40 pounds per cubic foot as the corresponding constants for wood, by a similar calculation the bursting speed is found to be 750 feet per second. This value would be modified slightly by the kind of wood chosen.

The weakness of the wooden wheel is

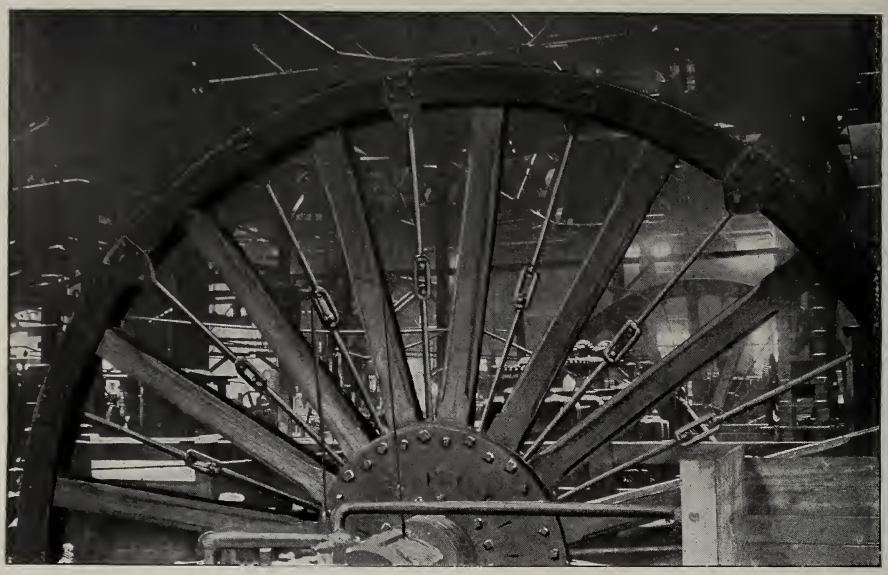


FIG. 14.—A CAST IRON WHEEL WITH WOODEN ARMS AND WROUGHT IRON TIE RODS

in the joints and the disposition of the fibre of the wood, and a great deal would depend on the care and skill used in arranging the segments and gluing up the wheel. Those familiar with the use of wooden pulleys on line shafting will see the force of this if they have not felt it. The most notable instances of the substitution of wood for cast iron in fly-wheels are the wheels at the factories of the Amoskeag Manufacturing Company, Manchester, N. H., and the Willimantic Linen Company, Willimantic, Conn., U. S. A. These wheels are 30 and 28 feet in diameter, respectively, and weigh over fifty tons apiece. They have wood rims built up on cast iron arms.

The most common cause of fly-wheel explosions is excessive speed, caused by racing of the engine, and these explosions are the most violent and disastrous. The rim of such a wheel, if of cast iron, will be moving at a speed of from two to five miles per minute, and the fragments may weigh hundreds of pounds. The original cause is usually failure of the governor to operate, due to breaking of the governor belt or of the gear connection, and to blocking of the safety device by the engineer,—the latter a crime which should be punishable by law. Fig. 13 shows the hub of a 24-foot wheel which burst under such conditions in a rod mill at Cleveland, Ohio. The governor belt broke and the automatic safety device was rendered inoperative by the blocking of the governor. The rest followed "as the night the day." Fragments of the rim weighing from 600 to 900 pounds were thrown to distances of over 600 feet.

The throttle valve in nearly all engines is in direct range of the wheel and requires several turns to close it. In one instance that came to the writer's notice the engineer was closing the throttle when the wheel burst and one fragment passed between him and the steam pipe, breaking the valve stem, but leaving him uninjured. No engineer should be asked or expected to put himself in such a death-trap as that. Some quick-closing form of valve in the main steam pipe, and out of range of the wheel, would render such risks unnecessary. Automatic devices should not be relied upon exclusively. "The unexpected which often happens" might be paraphrased so as to read:—"The automatic which seldom works."

Another less common accident is

caused by the sudden stopping of the engine due to water in the cylinder, or, in rolling-mill engines, to clogging of the rolls. The inertia of the heavy wheel rim carries it on and breaks either the arms of the wheel or some of the main connections of the engine. Most fly-wheels can be safely stopped in less than one revolution when going at full speed, but water in the cylinder does not give even so much grace. When a wheel is wrecked from any such cause the arms usually break off short at each end, leaving hub and rim clean. The rim may break up somewhat, but not into pieces, as when burst by excessive speed.

The wheel being nearly stopped before breaking, the fragments do not fly to any distance, and are sometimes found in the wheel-pit. If you must break a wheel, this is the safest way. Thus passed away the rolling-mill wheel shown in Fig. 13.

As one of the historical curiosities in fly-wheel design, the wheel shown in Fig. 14 is entitled to notice. This wheel is one of a pair on some blowing engines of uncertain date, which, until recently, were in use at one of the rolling-mills near Cleveland, Ohio. As will be seen from the illustration, the rim was cast iron in segments, with joints similar to those in Fig. 2, and similar wrought iron tie rods to keep the joints from bending. The arms, however, are of wood, and act simply as struts to keep the rim in place. The old veteran has this in its favour, it did not burst, and probably never will. Fig. 15 represents the latest stage in the development of the fly-wheel, illustrating one of the wheels now being constructed

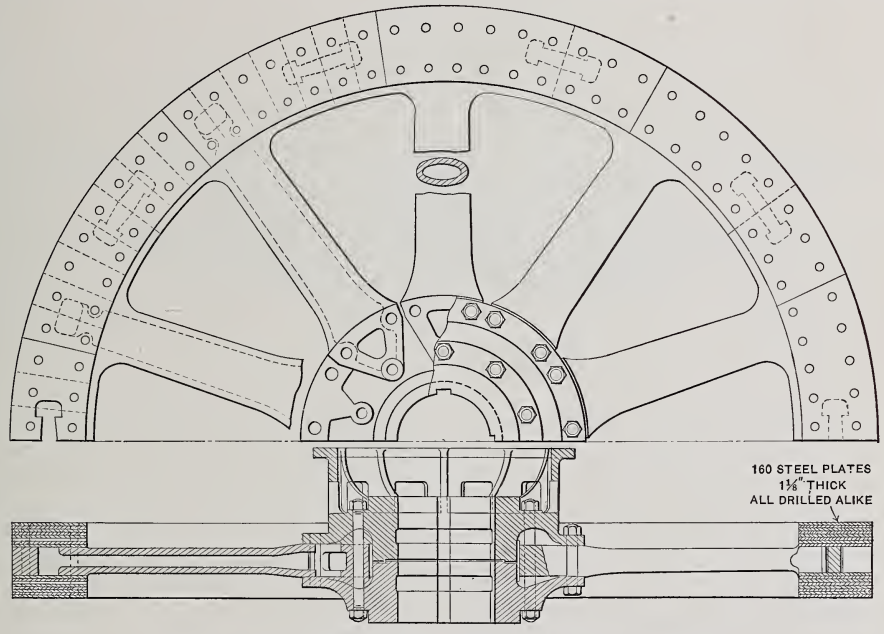


FIG. 15.—THE LATEST STAGE IN FLY-WHEEL DEVELOPMENT

for the Metropolitan Street Railway Company, of New York, by the E. P. Allis Company, of Milwaukee, Wis., U. S. A. It is of cast steel throughout, with the exception of the hub and the steel rim plates. These latter give an ingenious solution of one of the difficulties of rim design. They are riveted to the sides of the rim in such a way as to break joints effectually, and at the weakest point to offer seven-eighths of the maximum strength. They serve to reinforce the joints in the cast steel rim, so that the resultant efficiency of the whole is probably higher than that of

any wheel heretofore made. The wheel is twenty-eight feet in diameter, and weighs over one hundred and fifty tons.

As engine speeds and belt speeds increase, the use of structural and cast steel in fly-wheel construction would seem to be the natural safeguard against accident, and as the relative cost of these materials decreases, there can be no sound argument against their being employed.

"*Materia sana in structura sana.*"

Current Topics

COMPRESSED air for street railway traction has had its latest representative in the city of New York, where for a year or more, on two car lines, a series of very practical illustrations have been given of the fact that the compressed air motor is not an ideal tramcar motor, or rather that it is a most unsatisfactory tramcar motor, and the outcome of the experiment promises to be the early withdrawal from service of the compressed air cars, and, curiously enough, the experimental re-introduction on another line of electric storage battery cars. The latter undoubtedly owe this prospective new trial to the comparatively recent performances of electric automobiles in which storage batteries have given good evidence of ability to work satisfactorily under much more difficult conditions of service than those of the tramcar under which they failed repeatedly within the past ten years. During these ten years, however, the storage battery has been improved, and it is to-day in all respects a much more efficient piece of apparatus than the battery of the earlier trials. For special street railway service, therefore, where neither the overhead electric trolley nor the underground electric conduit is admissible, either because of local ordinances, in the one case, forbidding the stringing of overhead wires, or, in the other, because of excessive cost of construction, the storage battery car may now prove a commercial possibility. Complication of mechanism and a consequently heavy repair account appear to be now, as they always have been, the drawbacks to the compressed air car, and the failure of the system at New York was to be foreseen from experience with it elsewhere. In France, where compressed air has been applied to street railway service more extensively than anywhere else, twenty years' growth of the system is represented by only about 40 miles of line, and since the advent of the electric trolley there

has been no compressed air line extension whatever. In its proper field compressed air as a power medium has many attractive possibilities, but clearly that field is not to be found in street railway service.

THAT iron and steel constitute the barometer of trade, and that prosperity fluctuates with the rise and fall in the demand for those materials and in their prices, have long since become familiar sayings; and underlying them, too, is a solid stratum of truth. The most interesting questions to-day, therefore, from an industrial point of view, are what more remote causes have operated to create the world-wide prosperity of the last few years, and why was so much iron and steel needed everywhere. These questions, however, are more easily asked than answered. In the recently issued report for 1899 of the American Iron and Steel Association, Mr. James M. Swank, the secretary, apropos of this, explains that undoubtedly the great increase in the last few years in the world's supply of gold and its conversion into a circulating medium must be credited with a stimulating effect upon business generally in all progressive countries. Perhaps the absence of destructive European wars for nearly thirty years is a prime cause of the world's prosperity, for this freedom has promoted the welfare of European countries which are large consumers of agricultural and manufactured products, and it has led enterprising nations to develop the resources of less favoured and even benighted people. The leading causes of the increased iron and steel consumption are found principally in the enlarged use of iron and steel in shipbuilding and bridge-building, and the increasing use of steel in the construction of public buildings and private dwellings. The magnitude of this latter use has only recently been recognised. In the United States, too, steel cars are being substituted for wooden ones on railways, and to this one new departure a goodly share of steel industry activity is ascribed. The various uses to which electricity has been applied in late years, the water supply of cities, and all kinds of other engineering enterprises have also greatly increased the demand for iron and steel in all countries; and lastly, a new era in railway building has commenced in Russia, the United States, and some other countries, the great Siberian enterprises of Russia alone calling for immense quantities of railway material.

WITH the high price of copper and the steady cheapening of aluminium the use of aluminium wire for electric transmission lines is likely to become widespread, particularly, too, as experience with the wire in this field seems to favour the general conclusion that it can be safely used in place of copper wire. But proper precautions should be taken in inspecting it before it is erected, and due consideration also should be given to its peculiar properties of low and indefinite elastic limit, high coefficient of temperature expansion, and active electrolytic power. This last makes the choice of a proper joint a serious problem. According to Messrs. F. A. C. Perrine and F. G. Baum, in a paper on a 43-mile aluminium wire transmission line, recently read before the American Institute of Electrical Engineers, the aluminium wire, on the basis of the same conductivity, compares with copper as follows:—

Diameter for the same conductivity	1.27 times copper.
Area for the same conductivity	1.64 " "
Tensile strength for the same conductivity	0.629 " "
Weight for same conductivity	0.501 " "

The metal is so highly electro-positive that it is unsafe to expose it to the elements in contact with any other material, as electrolytic corrosion is almost sure to follow such construction. Many of the failures which have been reported of this metal have been due to a neglect of this fact; as notably in the case of the plates on the American yacht *Defender*, where the plates have been corroded at the contact with the bronze rivets used in fastening them to the frame. Whenever this metal is soldered or used in contact with any other metal,

the joint should be thoroughly waterproofed to prevent such action. After discussing many joints, Messrs. Perrine and Baum determined to abandon any attempt to solder or clamp the wire in any manner, and the joints were made by slipping the ends of the wire into an oval aluminium tube about 9 inches long, which was then twisted with a pair of clamps. After this a turn was taken, by hand, of the loose ends and the wire cut off close. The joint produced proved practically equal to the original wire in both tensile strength and electrical conductivity. The line was erected in California, during the winter of 1898-99, the temperature varying all the way from about 30 deg. F. to 80 deg. F. at times when the wire was being strung. After it was finally erected it remained about three months on the poles before the machinery was delivered and put in place. During the first month of that time three breaks occurred, which were all apparently due to flaws in the material; but after these breaks were repaired the line wire gave no trouble whatever, though various accidents occurred to other parts of the construction.

APROPOS of the widening use of aluminium in branches besides the one referred to in the preceding paragraph, Nicola Tesla, in the *Century Magazine*, predicts that the inevitable consequence of the advance of the aluminium industry will be the annihilation of the copper industry. They cannot exist and prosper together, and the latter is doomed beyond any hope of recovery. Aluminium, however, he goes on to say, will not stop at downing copper. Before many years have passed it will be engaged in a fierce struggle with iron, and in the latter it will find an adversary not easy to conquer. The issue of the contest will largely depend on whether iron shall be indispensable in electric machinery. This the future alone can decide. While it is impossible to tell when this industrial revolution will be consummated, there can be no doubt that the future belongs to aluminium, and that in times to come it will be the chief means of increasing human performance. It has in this respect capacities greater by far than those of any other metal. Mr. Tesla estimates its civilising potency at fully one hundred times that of iron. First of all, he says, we must remember that there is thirty times as much aluminium as iron in bulk available for the uses of man. This in itself offers great possibilities. Then, again, the new metal is much more easily workable, which adds to its value. In many of its properties it partakes of the character of a precious metal, which gives it additional worth. Its electric conductivity, which, for a given weight, is greater than that of any other metal, would be alone sufficient to make it one of the most important factors in future human progress. Its extreme lightness makes it far more easy to transport the objects manufactured. By virtue of this property it will revolutionise naval construction, and in facilitating transport and travel it will add enormously to the useful performance of mankind. But its greatest civilising potency Mr. Tesla considers to be in aerial travel, which, he thinks, is sure to be brought about by means of it. Telegraphic instruments will slowly enlighten the barbarian. Electric motors and lamps will do it more quickly; but quicker than anything else the flying machine will do it. By rendering travel ideally easy, it will be the best means for unifying the heterogeneous elements of humanity.

WOMEN as inventors are discussed by Dr. A. De Neuville in a recent issue of the *Revue des Revues*, French and American women being chiefly considered. According to a synopsis of the article, given in the *American Monthly Review of Reviews*, women as patentees were almost unknown in America before 1860, while since that time their number has increased to several hundreds. The first patent taken out in this century was for a machine for weaving straw mixed with silk or thread, the second for a corset, and the third for a

particular kind of cream of tartar and a powder for cake-making. Recent women's patents have mostly related to articles of furniture, type-writers, weaving machines, children's playthings, games, musical instruments, household utensils, gardening tools, or agricultural implements. One woman invented a hammock built for two, perhaps to serve the same end as the bicycle built for two. Another altruistically patented a mudguard for men's trousers. The best-paying patents are those for household filters and children's playthings and puzzles; but one woman has earned a small fortune merely through a glove-button hook, and another through a stay-busk. All the inventresses are not successful, any more than all their brothers are. But the proportion, be it noted, of those who profit by their patents is about the same in the two sexes. The most successful women inventors have begun with small patents, and gradually worked up to important ones.

As a patentee the French woman does not seem so successful as the American. The number of French inventresses, however, has rapidly increased, till (though the movement is much more recent than in America) it now rivals the number of American inventresses. In 1899, from May 1 till August 31 alone, seventy patents were taken out by women. The nature of these differs, however, very strikingly from the nature of those taken out by the American women. In time, if left to him, man might very well have done the American women's work; but it is hardly conceivable that he should ever have turned his masculine mind to the invention of a comb through which all sorts of delicate scents and essences can be conveyed to the roots of the hair and the head perfumed, or even an aromatic toothpick; nor is it likely that he would have shown his gratitude for the "mudguards" for his trousers by exercising his ingenuity upon the attainment of the ideal in women's bicycling or hunting costumes. Many American patents have been taken out by women at the head of large firms,—patents obviously owing their origin to some foreman or workman's brain. Dr. De Neuville considers that in matters where taste is of the first importance, requiring "the supreme delicacy of sentiment, the exquisite sense of the beautiful, which is the exclusive privilege of the Parisian woman," the French women will ever be queens. "Such," he says, "are the true inventresses; but they are too clever to have their inventions patented."

A MAKESHIFT of very useful character is found in a number of portable tool rooms recently provided at the United States Navy Yard at New York by Commander J. A. B. Smith. It was discovered that much time was lost by workmen running between the various dry docks and vessels, where they might be at work, and the tool room in search of the tools which they needed from time to time. To avoid this, according to *The Iron Age*, several frame buildings were constructed, each about 10×12 feet, with gable roof, and 12 feet from floor to top of gable. Steel bands passing under the buildings and up to the bottom of the gables had heavy steel rings fastened to their ends near the roof. In each of the little tool houses were erected an 18-inch drill press, a bolt and nut machine and pipe cutter, a set of emery wheels, an oil tank, a full complement of tools and other requisites. The machinery was belted to a 5 horse-power motor, which received its current from the general lighting system of the yard. When a gang of men is working at one of the dry docks or vessels anchored at the yard, steel cable bridles are swung over the house and hooked to the rings previously mentioned. The entire affair is then lifted by one of the 40-ton locomotive cranes which run about the yard, and is placed at an advantageous spot near the scene of operation. There is the usual check board in each house, and a man is placed in charge. During his spare moments he operates the pipe cutter and other ma-

chinery. His principal occupation in this connection is the making of nipples from scrap piping, and it has been ascertained that the man in charge of the house has saved more than twice his wages simply in the making of nipples. The entire shop weighs about five tons.

COMMODORE CHARLES H. LORING, U. S. N.

A BIOGRAPHICAL SKETCH

By Walter M. McFarland

IN every organisation there are men who, from the very beginning, seem to give promise of future distinction, and by their professional ability and readiness to accept duty, gain for themselves the requisite training, so that, when the time comes, they are ready to fill the higher positions which offer themselves. Such a man is Commodore Charles H. Loring, who has long been one of the conspicuous figures in the Engineer Corps of the Navy. He comes of good old Massachusetts stock, and was born at Boston in 1828.

His education was received in the public schools of Boston, which, even at that day, were noted for their excellence, as is attested by the Commodore's writings, which would never disclose the absence of a college course. Having selected engineering as his life work, he followed the approved routine of the time, for there were then no technical schools, and served a regular apprenticeship as a machinist. At its close, in 1851, he entered the navy as a third assistant engineer, attaining, by competitive examination, the highest place in a class of fourteen.

His entrance was just too late to give him an opportunity for participation in the Mexican War, and by the time the Civil War broke out he had passed through all the junior grades and had become a chief engineer. During his service in junior grades he had been laying the foundation for his more important work when an older man and in higher positions, a portion of his shore duty having been as assistant to the engineer in-chief of the navy, Mr. Samuel Archbold, in which capacity he had charge of the experimental work and tests of engineering devices coming before that office. It is interesting to note that while engaged in this duty he made a test of the first injector which came to this country.

During the Civil War he was in active service the whole time, and during the first eighteen months was fleet engineer of the North Atlantic Station, being attached to the fine old steamer *Minnesota*. He was on board this ship during the attacks of the *Merrimac* on the Northern fleet in Hampton Roads on the eighth and ninth of March, 1862, when the *Cumberland* was sunk and the *Congress* burned, and when the *Minnesota* also was attacked. A seven-inch rifle shot went through the Commodore's room; but, fortunately for him, he was at his post of duty in the engine room, so that he was not injured.

A little later he was detached from sea duty and sent to Cincinnati to supervise the construction of three river and harbour monitors and also of some light-draught sea monitors building there. Subsequently he was made general inspector of all the iron-clad steamers building west of the Alleghenies, having in charge at one time eleven monitors building at Pittsburgh, Cincinnati, and St. Louis.

During the Civil War a number of excellent engines had been accumulated for hulls which were in process of construction, but with the close of the war all work was stopped, and after a time

a board was appointed to recommend the best disposition of these engines which were stored in the various navy yards. It was about this time that the compound engine was coming into general use, and the same board was directed to make a study of the compound engine with a view to its introduction in naval vessels. Of this board Commodore Loring was senior member, and associated with him was the late Chief Engineer Charles H. Baker.

After a very exhaustive study of the subject, they recommended the introduction of compound engines and the abandonment of the simple form, and the conversion of a number of the engines which were on hand into compound engines. Four sets of these simple engines were so converted and were fitted to the *Vandalia*, *Marion*, *Quinnebaug*, and *Swatara*. The tests of these engines were very satisfactory and showed a coal economy for short runs of not much over two pounds of coal per horse-power-hour.

This study of the compound engine made it natural that Commodore Loring should be selected as the representative of the Navy Department when, in 1874, he and the late Dr. Charles E. Emery made an elaborate series of trials of the engines of the revenue cutters *Rush*, *Dexter*, *Dallas*, and *Gallatin*, to determine by actual test the relative economies of compound and simple engines, designed for the same work in similar hulls, and also to secure reliable and authoritative data with respect to the economy of steam jacketing. These tests were the first of the kind conducted under circumstances of entire reliability, with the result that the report of the trials was re-published all over the world, and is still quoted in all the text-books on steam engineering. The tests on steam jacketing were very valuable, and a study of these led to the suggestion of a re-heater between the high and low-pressure cylinders, a practice which is now almost universal in all economical compound engines on shore.

Commodore Loring's next tour of sea duty was as a fleet engineer of the Asiatic Station on the U. S. S. *Tennessee*, where he had as his chief assistant George W. Melville, who later became his successor as chief of the Bureau of Steam Engineering. There was nothing specially eventful in this cruise, and at its end, in 1880, he was assigned as the head of the steam engineering department of the New York Navy Yard.

This was the period of greatest inactivity in the history of the navy, and there was little to do, even for a very active man, except routine work. During this tour, however, Commodore Loring was senior member of a board that made a test of the machinery of the *Anthracite*, a little yacht with a triple expansion engine working with 600 pounds pressure. The experiments were valuable as showing that, with the form of apparatus on board the *Anthracite*, there was no such gain in economy as to warrant the tremendous pressure carried, while it involved numerous practical difficulties.

In 1881 he was a member of what is known as the "First Naval Advisory Board," appointed by Secretary Hunt to formulate a shipbuilding programme for the navy which he might submit to Congress. His engineering associates here were Commodore B. F. Isherwood and Chief Engineer Charles H. Manning. The personnel of this advisory board was distinguished in all its branches, and the work they did made possible our splendid fleet of to-day, as they definitely decided to abandon wooden hulls for those of iron and steel, and for general progress in every respect. In 1882 he was a member of another important board known as the "Navy Yard Board," of which Admiral Luce was senior member and Mr. A. B. Mullet, the supervising architect of the Treasury, a colleague. The duty of this board was to visit all the navy yards of the country for the purpose of determining which of them might with advantage and economy be closed. It was a delicate task, but the report, when finally approved, gave general satisfaction, and its recommendations were carried out.

On the retirement of Engineer-in-

Chief Shock, only two successors were thought of, one of whom was Commodore Loring, and his merit and thorough qualification for the position were so well recognised that the appointment came to him entirely unsought. This was in 1884, during the administration of President Arthur. Secretary Chandler was presiding over the Navy Department at this time, and it was under his supervision that the four vessels commonly known as the Roach cruisers, the *Atlanta*, *Boston*, *Chicago*, and *Dolphin*, were built.

Part of the scheme of building the new navy was the organisation of what was known as an "Advisory Board," composed of two civilians and a number of naval officers. Owing to this *régime* the bureaus were not given the same free hand that had obtained since the advisory board was discontinued, although they did valuable work in the details of designs. Forced draught was used on these new vessels, after having been tried on two others,—the *Alliance* and *Swatara*,—under Commodore Loring's direction.

In 1885, with the advent of a new administration, there was a general spirit of unrest about the Navy Department from what seemed to be a prevailing belief that whatever was, was wrong. The air was filled with rumours of intended changes, among them one which promised to cause a violation of the contract labour law, as it was actually seriously under consideration to import a British engineer and put him in charge of the design of machinery. From this intent and other indications it became evident to Commodore Loring that he did not enjoy the Secretary's confidence, and he tendered his resignation.

After leaving the Bureau of Steam Engineering he was made senior member of the Experimental Board of Naval Officers at the New York Navy Yard, which board, under his direction, conducted many exceedingly valuable experiments. Among the most important were the competitive tests of water-tube boilers to determine the type that should be used on the coast defence vessel *Monterey*, and it may be well here to call attention to the fact that this was the first case on record where a boiler had ever been run for twenty-four hours when burning more than fifty pounds of coal per square foot of grate.

Another very important series of experiments conducted by Commodore Loring were those on the boilers of the torpedo-boat *Cushing*, to determine the economy of evaporation with different air pressures and rates of combustion. These experiments have proven of the greatest interest, and form a very valuable collection of engineering data. A number of clever devices had to be schemed out to carry on these tests, and the whole success was a great credit to Commodore Loring and the board.

Having reached the age limit in December, 1890, he was placed on the retired list; but having always been a man of very vigorous physique, he did not give up active employment, and was for a time consulting engineer to the United States and Brazil Mail Steamship Company. During the late war with Spain he was recalled to active duty and assigned as inspector of engineering work in New York City.

What has been said thus far is simply a sketch of professional work done by Commodore Loring, but it gives little idea of the man himself, and it is his personality which is of most importance to his friends. He is a man of peculiarly lovable disposition, and one who wins the affection of all who are brought in contact with him. As an after-dinner speaker he is always a success, but probably he is at his very best with a party of congenial friends, when his remarkable skill as a raconteur has an opportunity for full play. His personal popularity is shown by the fact that for two years he was president of the Engineers' Club in New York City, and for one year president of the American Society of Mechanical Engineers. He is first vice-president of the Army and Navy Club of New York, and also one of the vice-presidents of the Society of Naval Architects and Marine Engineers. He is still hale and hearty, and does not look his age by ten years.

Benjamin F. Isherwood.

ENGINEER-IN-CHIEF OF THE UNITED STATES NAVY FROM 1861 TO 1865

SEE PAGE 344

AUG 8 1900

CASSIER'S MAGAZINE

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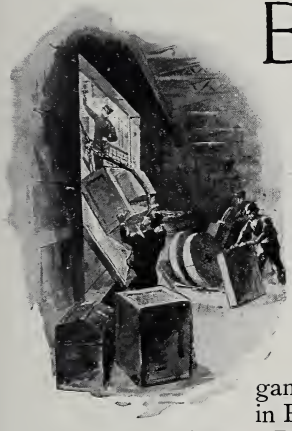
ELECTRIC CRANES IN GERMAN HARBOURS

By Louis J. Magee



BUSIEST and largest of all Continental ports, Hamburgh has for the last two decades been the seat of marked engineering activity. This "Free and Hansa City," for that is its official designation, is one of the three survivors of the Hansa league, that first systematic organisation of commerce in Europe. Like its two Hansa sisters, Bremen and Lübeck, Hamburg is a sovereign State in the Imperial Federation. It is a democracy which takes its independent place in the German Empire on a par with Prussia and the other kingdoms, principalities or dukedoms. Up to October 15, 1888, Hamburg was also "free" in another sense,—its inhabitants had no duties to pay on importations of any kind. Customs officials could be found only at the railway stations and on the high roads leading to the surrounding, Prussian, territory.

In 1888 the city gave up its customs "freedom," but at the same time that it was placed on a par with other German States and cities a certain district (2470 acres) was set apart and enclosed as a "free harbour" outside of the customs boundaries of Germany. This district, known as the "Freihafen," is a sort of bonded warehouse district, where the formalities of bonding, however, are unnecessary. Private residence in the district is not permissible. The convenience offered by the "Freihafen" contributes immensely to Hamburg's value as a centre of trade. The wine, coffee, or tobacco merchant keeps the principal part of his stock in his "Freihafen" warehouse. What he sells to Germany he pays duty on when he takes it across the bridge to the city, or loads it into a freight car for Berlin; the other part of his stock, which he sells to Russia or Sweden, is lowered from his warehouse door into a lighter and then brought alongside a steamer bound for Reval or Stockholm. The changes from ship to lighter, and from lighter to storehouse, may go on interminably without the slightest cognisance on the part of the customs department, so long as these changes take place within the free-port district. The warehouses have 900 acres of floor space and capacity for 400,000 tons of merchandise.

A British or an American manufacturer of machinery doing business all over Europe would find it exceedingly expensive and troublesome to carry a complete stock in each Continental capital, but he may, at comparatively small expense, maintain a central stock in the Hamburg free-port, ready for instant

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FIG. I.—THE POWER STATION FOR THE HAMBURG HARBOUR CRANES

shipment by water or rail, not only into Germany, but to all Europe and to the ends of the earth. Not only goods in warehouses, but also large stocks of coal, tanks of petroleum, and great mounds of guano and nitrate and other commodities requiring large open spaces, as well as factories and shipyards, lie within the free-port boundaries. Commercially, the "Freihafen" is a neutral clearing house, a re-shipping island in the ocean of trade, politically distant from all countries, and still the convenient door to Northern Europe. Full appreciation of this world-transit character of Hamburg's commerce is necessary in order to grasp the seriousness of the demands made upon its harbour facilities. The larger part of the nine million tons of merchandise entering Hamburg annually by sea finds only a temporary resting place on German shores. The "Freihafen" was built by the Hamburg State, and is under the immediate supervision of the "Building Deputation, Department for the River and Harbour." The various types of vessels, whether steamers or sailing ships, all have their special places in the harbour, and various types of cargo, as, for instance, petroleum, have special districts. Ships lying in the petroleum harbour, for example, are not allowed to have cooking on board. The convenience, comfort, and efficiency of the customs guard over, and the despatch of, goods entering Germany by water (that is, by the Elbe above Hamburg) have been provided for with floating pontoons anchored in the harbour, fitted out with one hundred hand-cranes, weighing scales, examination sheds, and well-lighted and heated offices. About ninety miles of railway track lie within the "Freihafen." Ten miles of quay frontage provide room for three hun-

dred seagoing vessels. Warehouses, bridges, locks, landing stages, and stairs have all been carried out with remarkable forethought and ingenuity, and the architect has worked with the engineer.

As late as 1866 ships entering Hamburg harbour lay alongside rows of wooden piles (Duc d'Albe) on natural bays and byways of the river. The warehouses lined the canals in what was then the very heart of the city, as they do to-day in parts of Hamburg, and lighters served to carry all the goods between these houses and the ships in the harbour. Special harbour conveniences were not provided. In 1862 the first quay was commenced, and in 1866 ships could unload directly into sheds or railway waggons.

The building of the "Freihafen," which commenced in 1884, gave, of course, vast impetus to the harbour improvements which had been going on uninterruptedly for years. Cranes of all sizes and types have been installed with great liberality. The harbour authorities have about 550 under their charge, not including cranes belonging to the railway or to private companies, factories, and shipyards, and excluding also warehouse hoists. Some of them are fixed on the quay walls, and some are portable on rails. There are 264 portable steam cranes, a part of them for 1½ tons and the rest for 2½ tons; most of them are self-contained, but a number receive steam from a central station. There are about a dozen hydraulic cranes, these being supplied with water from a large pumping plant and accumulator which drives the elevators and hoists in the warehouses. Furthermore, 136 hand-cranes are to be mentioned.

FIG. 2.—AN INTERIOR VIEW SHOWING DIRECT-CONNECTED GENERATORS AND SWITCHBOARD

Although the 1 to 2½-ton cranes are most numerous, there are various larger cranes scattered about the harbour. The 40-ton hand-crane is an interesting

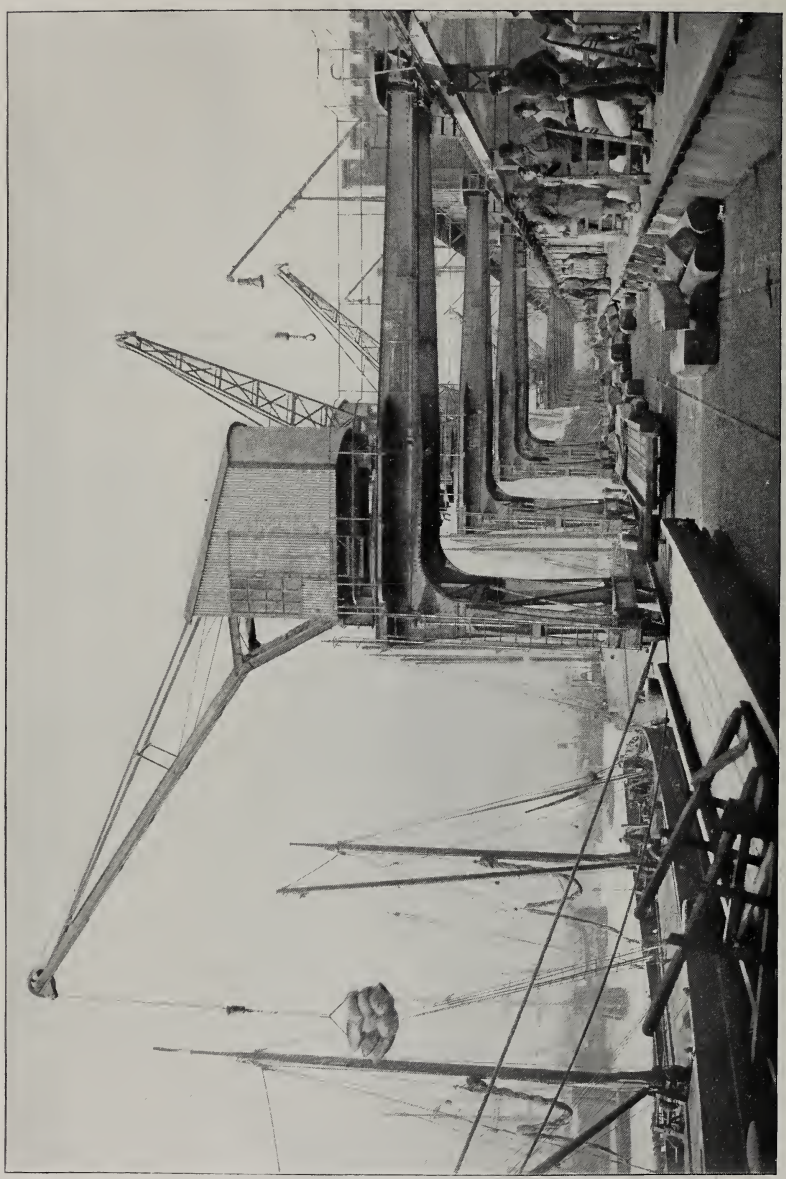


FIG. 3.—A GENERAL VIEW OF THE CRANES, LOOKING ALONG THE WAREHOUSE LINE

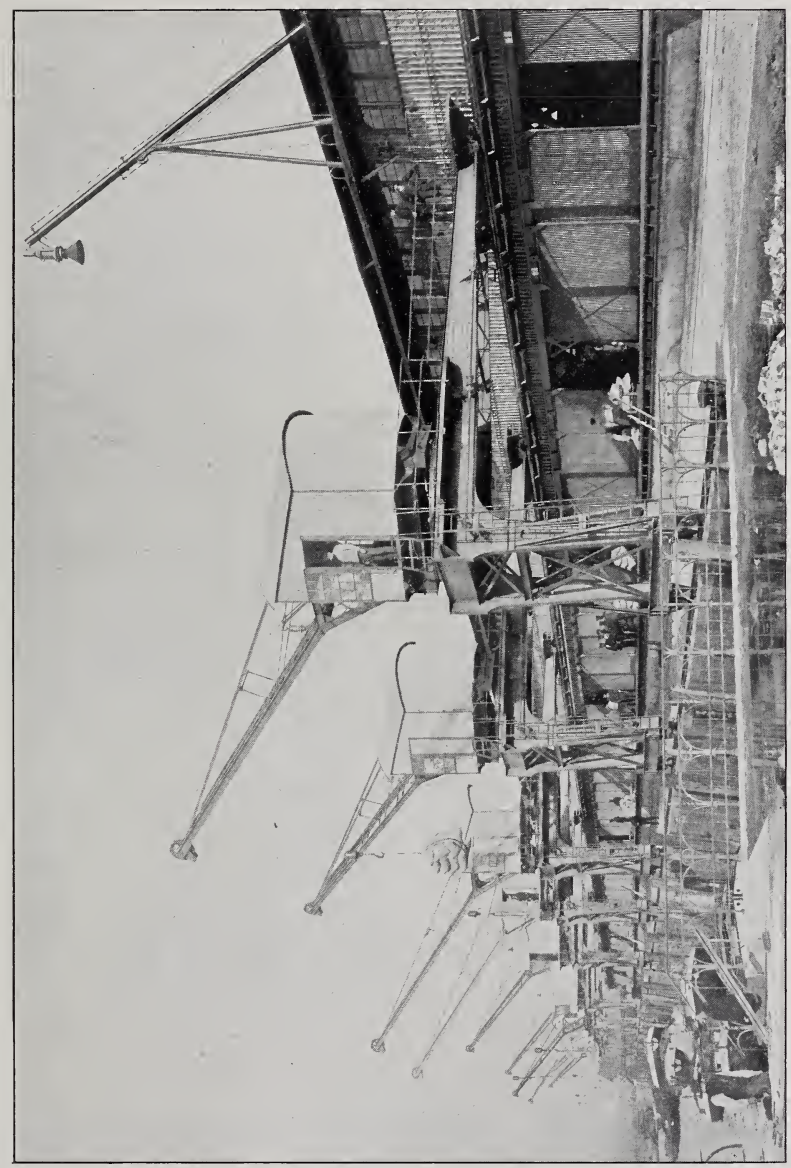


FIG. 4.—A PARTIAL FRONT VIEW

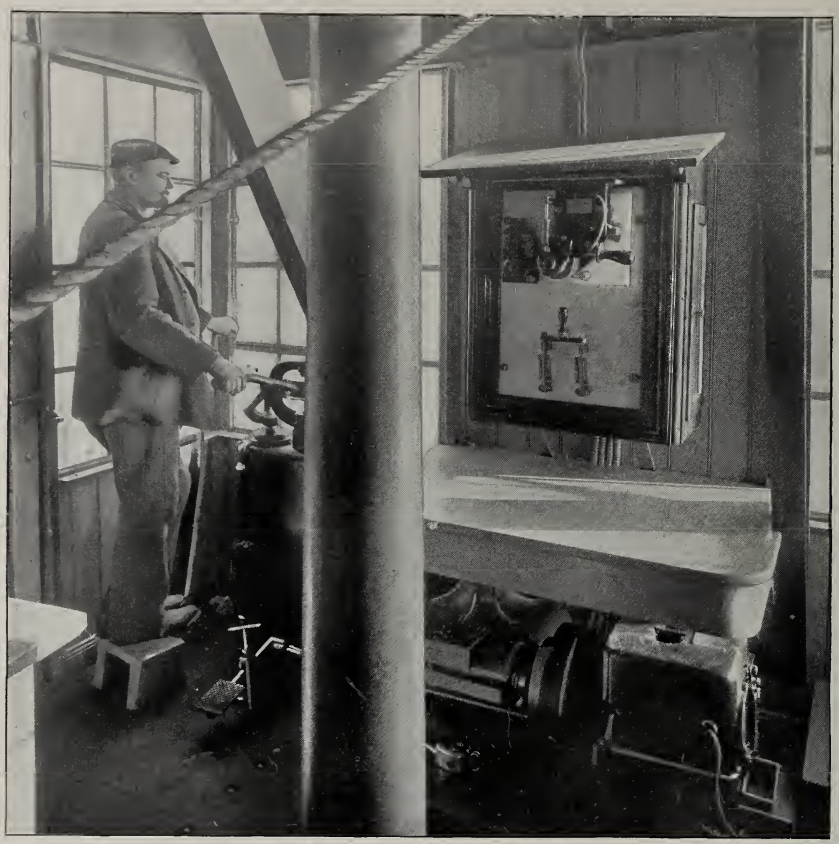


FIG. 5.—INTERIOR OF ONE OF THE CRANE CABINS, SHOWING THE MOTORMAN AT HIS POST. THE SLEWING MOTOR IS SHOWN UNDERNEATH THE TABLE

affair, as also the 50-ton and 150-ton steam cranes, the latter having served to load many a Krupp gun, and having for some years enjoyed the reputation of being the most powerful harbour crane in the world.

Early in the nineties electric cranes were tried and practically abandoned, for here, as elsewhere, electric apparatus seemed to be comparatively late in adjusting itself to the practical requirements. The high speed of the motors, the mistake of trying to perform all movements with one motor instead of having a motor for each movement, the unprotected design of the motors themselves, and the clumsiness and fragility of the regulating apparatus were troubles just serious enough to outweigh the recognised advantages of electric power distribution. The ironclad, waterproof, low-speed, continuous-current series motor, and that "liberally applied" (a motor for each movement), seemed to be the key to the final solution.

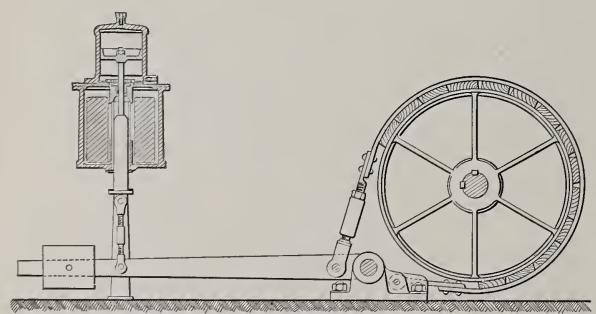


FIG. 6.—THE SOLENOID BRAKE ON THE HOISTING MOTOR

It is the result of street railway and mining locomotive practice and was adapted from America.

The modern controller, likewise developed in street railway practice, is the second element in the success of the electric cranes. Where two motors are used, their controllers may be mechanically combined through a universal joint and manipulated with one handle. (See Fig. 7.) This arrangement, patented by the Union Elektricitäts Gesellschaft, of Berlin, and applied by them to hundreds of cranes, has proved most efficient for the cranes in Hamburg. The hoisting and turning motors are under work together with any desired ratio of speed. It is at once evident that the motorman is relieved by this simple arrangement from the necessity of the close attention which two sets of handles would require, and his whole attention is confined to a nice placing of his load and a time-saving combination of hoisting and slewing. The experience with cranes and hoists on Lloyd liners, which are served by local dockmen, quite established these "universal controllers" as indispensable parts of the plant. Neapolitans, Malayans and Chinamen soon felt as much at home

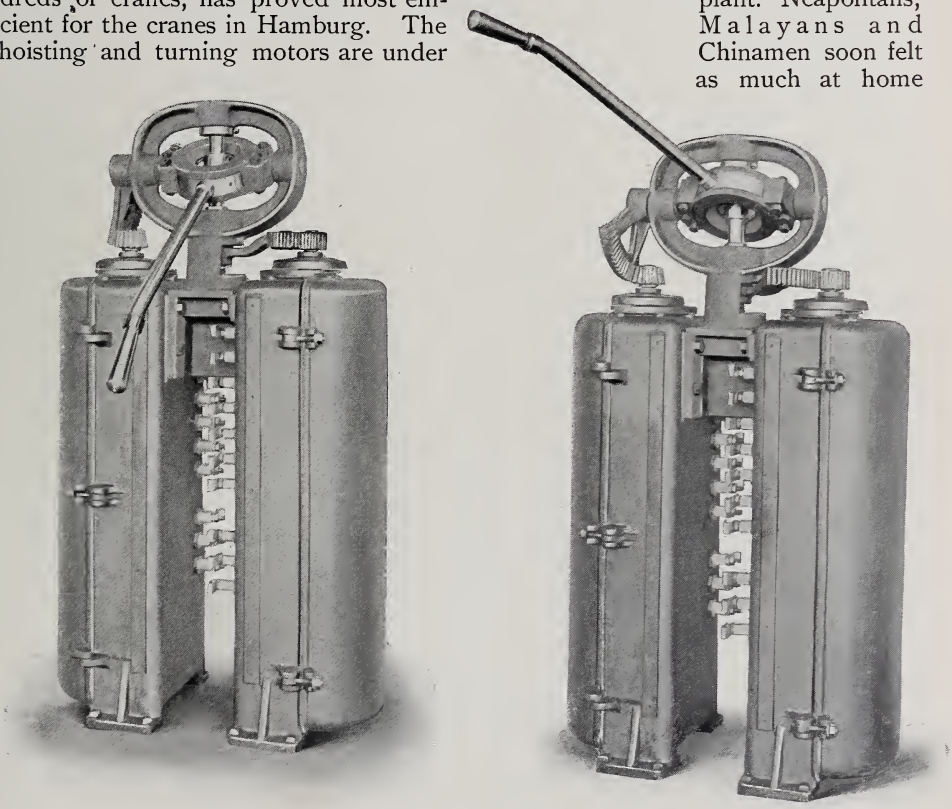


FIG. 7.—THE DOUBLE CONTROLLER, SHOWING THE HANDLE IN DIFFERENT POSITIONS

one hand. The load follows, in direction, the movement of the handle. Pressing down the handle lowers the load, for it operates only one controller, leaving the other at the zero point. By turning the handle horizontally, the other controller is operated, and the crane swings about. A diagonal movement combines these motions, and both motors then with the controller handle as they had formerly with the steam winches.

The electrical cranes in Hamburg harbour serve principally a portion of the new wharves leased to the Hamburg-American Line. They are operated by employees of this steamship company. The State, which owns the cranes, also owns the central station and furnishes

FIG. 8.—THE BOILERS IN THE POWER STATION

current to the users of the cranes. The method of mounting the normal harbour crane which has proved very satisfactory in Hamburg consists of a bridge, or gantry, spanning the railway track and supported at one end by a rail running along the warehouse wall, while its other end is movable on a rail laid along the edge of the quay. This is shown in Fig. 3.

As to the electrical outfit of the crane, it is important to emphasise the desirability of a rapid return of the empty hook at a small power output, and the handling of light loads at speeds much above the normal. This means a great deal in the total economy, and means a great deal, too, for the captain of an Atlantic liner who is anxious to complete loading and take advantage of high tide to drop down the River Elbe. This point speaks for the continuous-current series motor, as opposed to the shunt motor and the alternating-current induction motor, whose speed is practically constant, regardless of load. It is, of course, assumed that the reduction gearing remains unchanged for all loads.

The advantages of induction motors for continuous running decrease materially when the operation becomes intermittent, as in crane plants. In induction motors the much-abused commutator is, to be sure, dispensed with; but collector rings and regulating rheostats

must be used. The speed can be regulated only below the desirable normal speed and at cost of efficiency. Furthermore, the power factor of an induction motor plant becomes a serious consideration with intermittent loads and variable service. Hoisting motors with 300 revolutions per minute are about as high as the usual drum diameter and single reduction will allow one to go, and the reduction of this speed is desirable. This would mean, at fifty cycles per second, a comparatively large three-phase motor. The continuous-current series motor is inherently adapted to crane driving as no other type of electric motor is. Of course, the strongest argument for the system and the types chosen was the experience already gained in other cranes and hoists, and, behind that, the street railway experience. The generator voltage of 550 came naturally as the tried maximum for which all details are worked out, and was sure to operate well, while a lower voltage would only have increased the cost of conductors.

The 56 "Freihafen" cranes (Fig. 4), as built by the Beurather Maschinen Fabrik, near Düsseldorf, and equipped electrically, as well as partly designed, by the Union Elektricitäts Gesellschaft, of Berlin, are intended for a normal load of 5500 pounds and a testing load of 7000 pounds. The gantry on which the crane is mounted is called a "Portal," and this general type is usually referred to as a "Portal-Krahn." A detachable handcrank serves, through double gearing, to drive the wheels on which the lower limb of the portal rests. The weight of the load, the cabin, and the driving machinery is borne by a carriage which radiates on a central steel pillar. This runs on four wheels and a circular track. As the crane is provided with a counter-weight, the pillar is not subjected to much strain, but serves only as a guide in rotating. The 7 H. P. slewing motor is coupled to a worm gear. The turning of the crane is surprisingly noiseless. The drum gear is driven by a pinion on the shaft of the main motor. This motor can give 35 H. P. at 310 revolutions per minute, and drops to 275 revolutions per minute at 47 H. P. The hoisting gear is also practically noiseless, and the pull on the cable is gradual. The load is held at any position by a solenoid brake (Fig. 6) placed in series with the main motor and arranged to raise a weight and release the brake when the motor is cut in. As soon as the current is cut off from the motor, and, therefore, also from the brake-coil, the weight falls and holds the drum fast. An air

FIG. 9.—A ONE-TON CRANE AT HARBURG

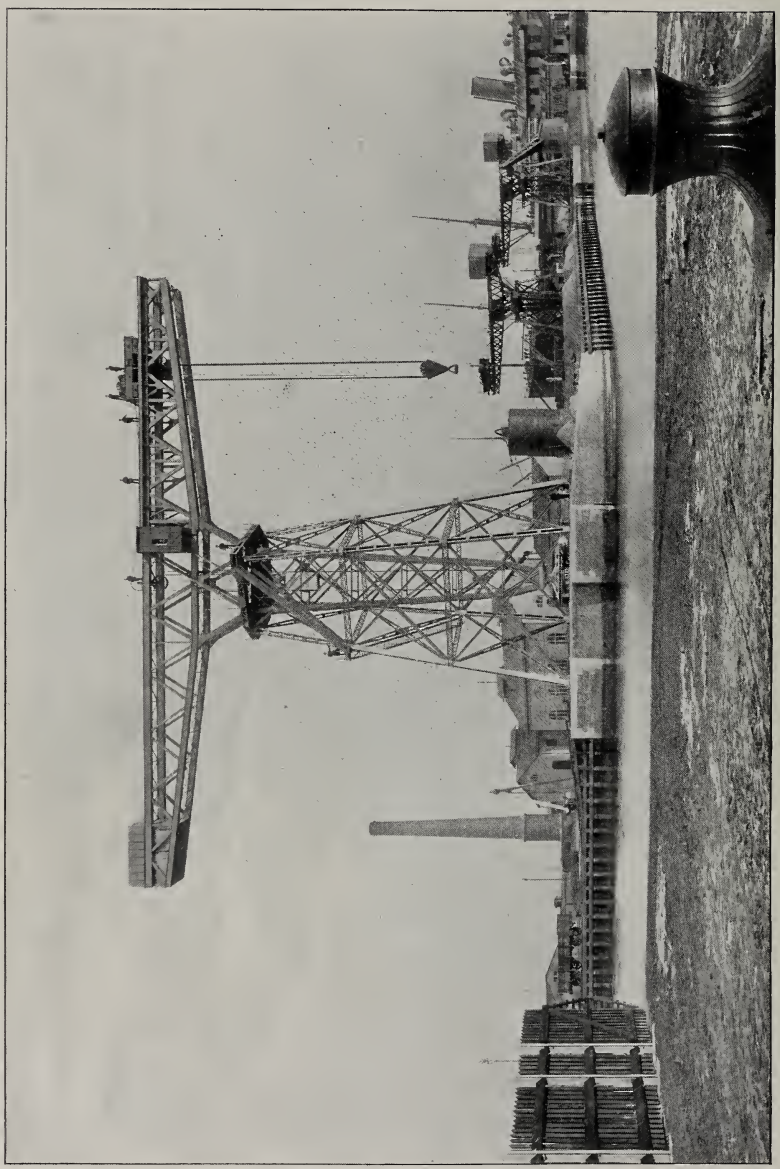


FIG. 10.—A 150-TON CRANE AT BREMERHAFEN

dash-pot provides against too sudden an action of the brake. An arrangement is also provided for mechanically loosening the brake so that the load can be dropped gently without current in the motor. A mechanical foot-brake is also attached for the slewing movement.

Water-tight connection boxes are arranged at intervals along the shed wall, and to these flexible cables leading to the crane through the hollow spindle on which it turns are attached at will. The switchboard is provided with a lamp, a current indicator, and a circuit-breaker to prevent danger from overload or improper manipulation. Fig. 5 shows the interior of the cabin.

The average amount of energy required for a complete crane evolution, consisting of hoisting the load 49.2 feet, slewing the jib through an angle of 140°, lowering the load to the platform of the shed, raising the empty hook to its highest point, slewing back again and lowering the hook to its original position (slewing and hoisting taking place partly at the same time), is as follows:—

Load on Hook. Lbs. Engl.	Watt Hours per Evolution.	Cost of Current— Per Evolution.	Cost of Current— Per Ton Unloaded.
5,500	186	1.56 cents.	0.63 cents.
3,300	135	1.13 cents.	0.77 cents.
1,100	75	0.63 cents.	1.3 cents.

The cost of current is based on the established price of 8.4 cents per kilowatt-hour (35 Pfennige) at which the harbour authorities furnish current to the Hamburg-American Line. Much lower prices for large power customers obtain in Hamburg, and it is hardly necessary to state that one can produce one's own current in many cities for a fourth of this price, including fixed charges.

The table shows that, while it costs only six-tenths of a cent to unload a ton in packages of 2½ tons, it costs over a cent per ton if the packages weigh only half a ton. This results, naturally, from the fact that the energy consumed by the crane itself shows up more on light loads, that is, that the total efficiency decreases with the load. Appreciating this point, the Hamburg-American Line instructed their New York agents to arrange for packages conforming (as nearly as the nature of the merchandise permits) to the normal crane capacity of 2 to 3 tons. While the efficiency on small loads is lower than with large loads, this is, thanks to the series motor, partly compensated for by the fact that the light load is hoisted in half the time. The speed ranges ordinarily from 2 feet per second with 3 tons to 4.1 feet with half a ton. Naturally, if the hoisting heights and slewing angles are less than in the crane cycle or evolution for which the average figures were given above, the costs will be reduced. One hektowatt-hour per crane evolution, for loads of about one ton, averaged over loading and unloading operations, might be a fair figure for rough calculations. Ordinarily with light loads (unloading

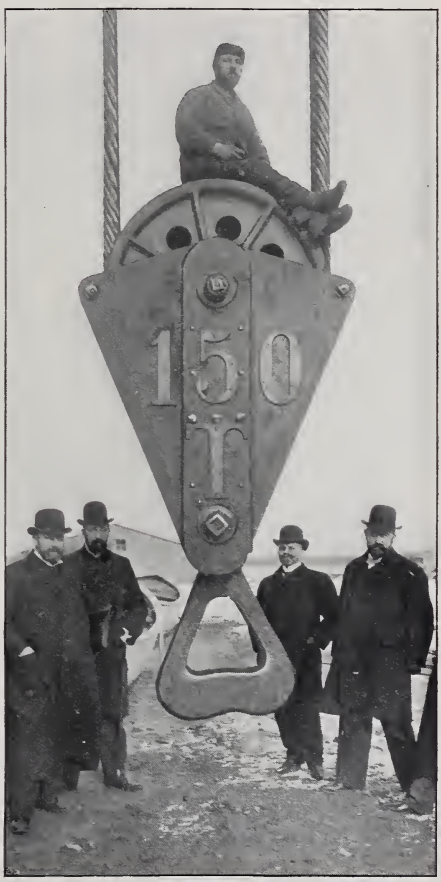


FIG. 11.—THE HOOK OF THE 150-TON CRANE

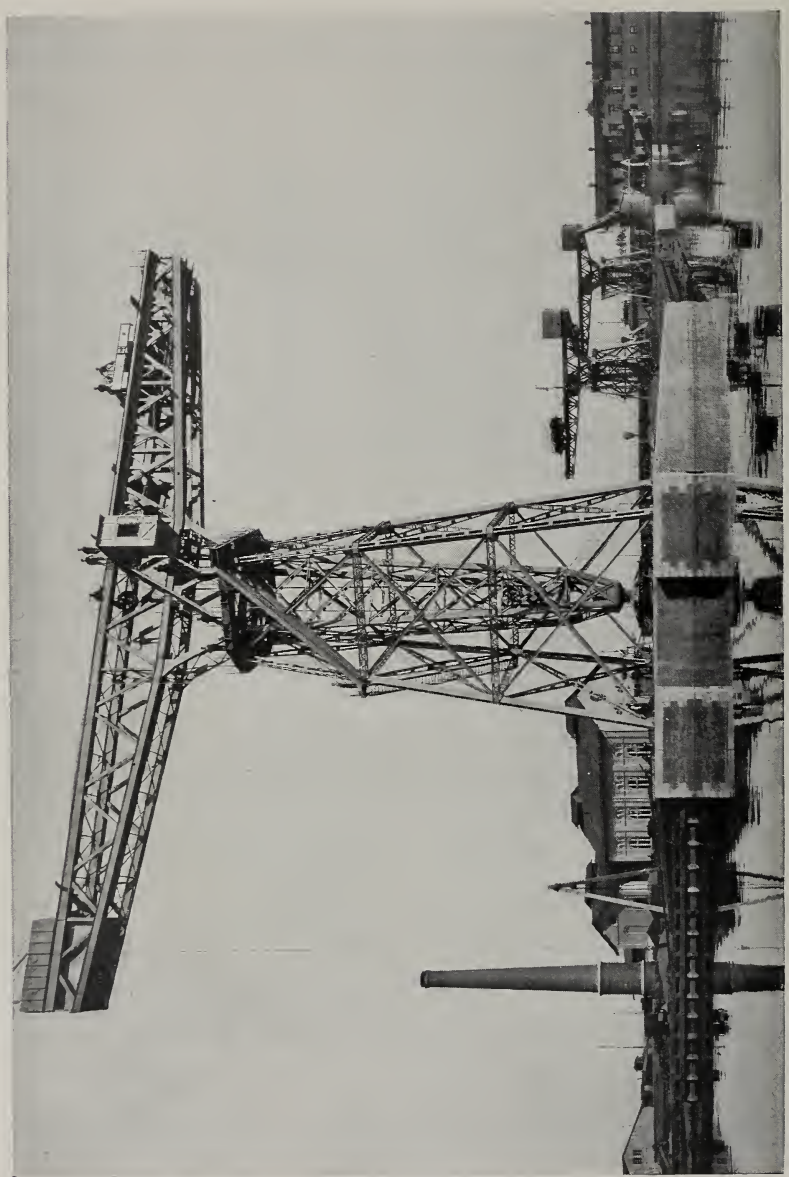


FIG. 12.—ANOTHER VIEW OF THE 150-TON BREMERHAFEN CRANE

ships) 15 to 18 trips per hour are made, whereas it is common to increase the number to 26 when cranes and men are hurried. The empty hook must, according to specifications, descend from its own weight, but a slight impulse is usually given it from the motor to hasten the return.

The jib extends 29½ feet out beyond the quay wall, and the slewing radius is 36 feet. The rails between which the gantry is spanned are 35 feet apart in horizontal distance, the rail on the wall being 16.8 feet above the rail on the quay.

The free height beneath the gantry is 16.2 feet. The maximum hoisting height is 72 feet.

Of the fifty-six harbour cranes above described there are two provided with traction motors instead of hand wheels for moving the gantry. Furthermore, there are numerous electric winches for use in the sheds. Thirty-six additional harbour cranes, conforming in their general design to those already described, were furnished by other contractors.

The power station for supplying the cranes and the lighting of the quays and sheds, shown in Fig. 1, forms a pleasing element in the general view of the new part of the harbour. The storage battery is placed in two rooms, one above the other, ingeniously worked out in the form of a tower which constitutes an architectural connection between the engine room, boiler house, and repair shop. The station contains, at present, four direct-connected, 550-volt, shunt dynamos, two of them being of 160 KW. capacity, one of 225 KW., and one of 325 KW., in toto, 870 KW. The generators work in parallel with a battery of 296 ampère-hour capacity at one-hour discharge. Despite the large number of cranes in operation, the load is sufficiently irregular during the course of a few minutes and sufficiently variable during the course of a day to render the storage battery an economical as well as a steadying adjunct to the plant, as such "buffer" batteries have proved to be in many railway plants.

The quays and sheds are lighted by 145 enclosed arc lamps burning five in series and fed from the same source as the cranes. A special battery is provided for the incandescent lamp lighting on the three-wire system with twice 190 volts. This battery is charged during periods of light crane loads. The power station, with its present equipment, was designed for 100 cranes, 16 winches, 230 arc lamps, and 1400 incandescent lamps, but will suffice for still further enlargements of the crane plant, as the load factor has, up to date, proved

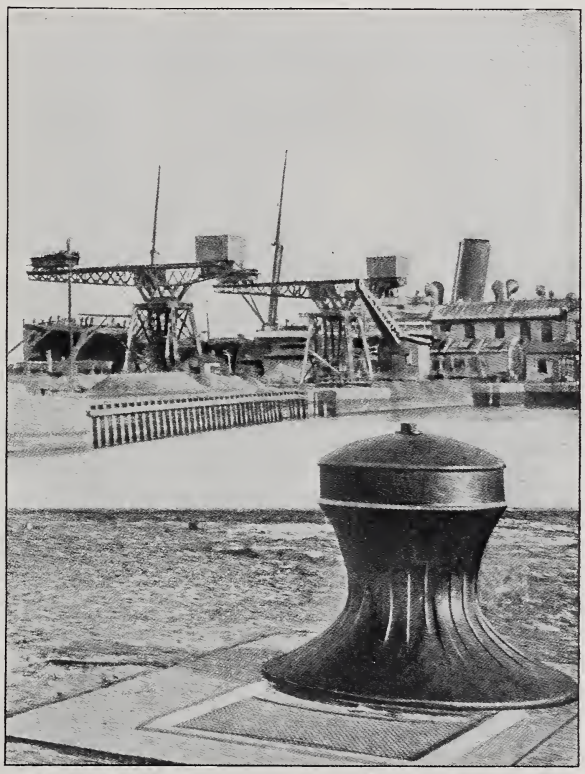


FIG. 13.—A NEARER VIEW OF THE ELECTRIC CAPSTAN SHOWN IN FIG. 10

more favourable than was expected. The steam plant is first-class and conveniently arranged. A spacious cellar contains the piping, pumps, condensers, and other accessories. The boiler house (Fig. 8) and repair shop are well equipped, and are kept as clean as a model kitchen. The interior of the dynamo-room, with its polished granite foundation cappings, white glazed walls, travelling crane, tiled floor, and marble switchboard panels, shows that the harbour authorities indulge in a tasteful solidity, with touches of luxury.

Although the importance of this plant in Hamburg is of the first order, some very interesting large cranes have been installed by the two companies mentioned above at the new dry dock in Bremerhafen. The building of the North German Lloyd steamship *Kaiser Wilhelm der Grosse* required important improvements in the River Weser, along with which the Lloyd also built the enormous "Kaiser Dock." The 150-ton giant crane (Figs. 10 and 12) furnishes direct communication between the largest steamers and the railway system of Germany. Fig. 11 shows the hook of this crane. The hoisting is done with two ironclad, 35 H. P. series motors. Another motor, of 26 H. P., serves to rotate the monster. All the operations are controlled by one man in the cabin high up on the bridge. He has one hand on a controller, for hoisting, while the other hand operates a "universal controller" handle for travelling and slewing. The box at the left end of the trestle is a counter-weight of sand.

The two large 50-ton cranes in Fig. 13 and in the background of Fig. 10 are placed on either side of the dry dock, for handling plates, engine parts, etc., for ship repair. The 20-ton crane, appearing just under the sand box of the right-hand crane in Fig. 13, is mounted on a pontoon which serves to close the entrance to the dock. The gates are operated electrically, and so, too, are three large capstans (Fig. 13) located at either side and at the end of the dock. The 18 H. P. capstan motor, controller, and main switch are reached by the trap-door in the foreground, the controller being operated by a long T-wrench. The service pressure for this installation is 110 volts. The operation of these cranes is remarkably simplified by the use of electricity. The conductors are laid in Bergmann tubing. The compactness of the electrical parts, and the insignificant appearance of the motors, as compared with the ponderous masses which they can move so easily, is remarkable.

As interesting installations of a similar nature, carried out by the Union Gesellschaft, the writer would mention two portal cranes in the harbour of Düsseldorf, four cranes and numerous capstans, hoists and coal-conveyors in the harbour of Breslau, a 100-ton crane in a Bremen shipyard, and a neat type of 1-ton fixed dock crane, for factories, with harbour frontage (Fig. 9), at Harburg.

A number of simple hoists have been equipped also on special lighters owned by the Hamburg-American Line. The novelty is that they get their current through flexible cables which they connect to plugs on any trans-Atlantic steamer to which they may tie up. They serve for coaling, but could also be used in any case where a floating crane is desirable, that is, where a ship's own hoists are not available, and the ship, not being in dock, cannot be served by hand-cranes.

Salt has a preservative effect on ideas and customs as well as on meat, and those who "go down to the sea in ships" or work about harbours are peculiarly conservative and distrustful of new ways of doing things. All of those who have listened to the gossip of the bridge and engine room know how "Old Experience," in gold lace and blue, scoffs at various novelties invented on land. To pass muster on the sea and on the wharves a novelty must be really a good thing, and sometimes even when it works perfectly, it will be left unused on the plea that it is unnecessary.

The above-mentioned electrically-driven harbour cranes, which have satisfied so well not only the engineers who

ordered them, but also the plain folk whose labours are lightened by them, are one more indication that electrical apparatus has come a step nearer that general application which it is so trite to predict for it. A busy row of electric cranes flinging merchandise into the vast sheds on the "O' Swald" and "Amerika-Quai" shows that the electric motor has reached that stage long since enjoyed by the donkey-engine where it does its work in spite of the "care" it gets, where it asks no favours above those conceded to any fellow member of the "machine-kind."

The thin atmosphere of electrical science has been abandoned and the motor has come down to the every-day greasy, long-suffering existence of the steam engine.

THE SLOOP-OF-WAR "WAMPANOAG"

A ONCE FAMOUS, BUT LONG FORGOTTEN, UNITED STATES CRUISER

By Chief Engineer B. F. Isherwood, U. S. Navy

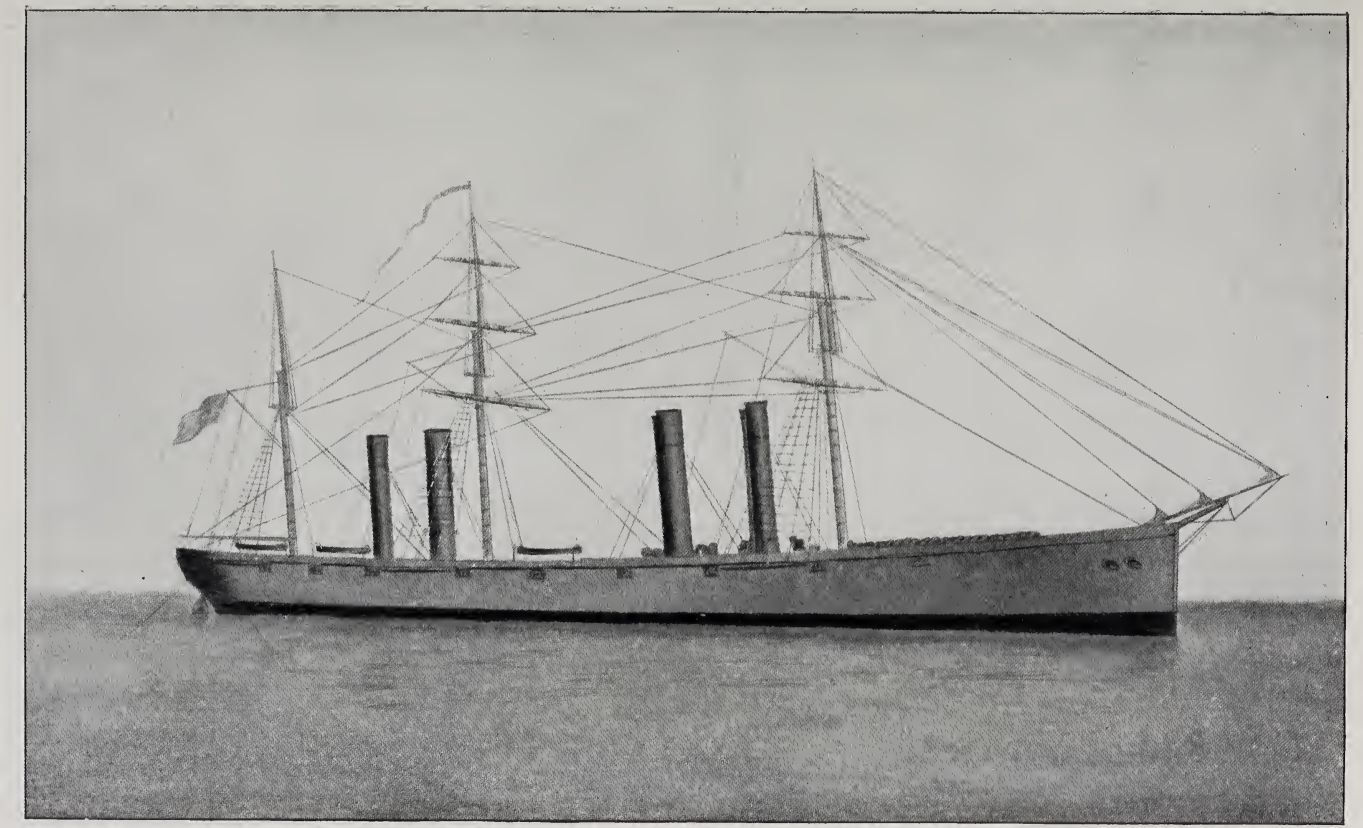
AS a matter germane to the late war between the United States and Spain, the issue of which depended primarily on naval sea power, it will be interesting to revert to a long forgotten vessel of the United States Navy which was really the precursor of the modern so-called cruiser, and which, though a novelty at the time, had qualities and capabilities that still make it an object of interest both for example and instruction.

The vessel in question was a real cruiser, being fitted with full sail power and having a coppered bottom; consequently she was able to keep the sea indefinitely, while her successors are only nominally cruisers with sphere of action and time endurance limited by the weight of coal in their bunkers, and by the continuous degradation of their speed, due to the rapid and great fouling of their steel bottoms. In these very important particulars of radius of action, sustained speed, and endurance, the prototype vessel was vastly superior to those which have been developed from her.

This vessel was the once much-discussed and well abused *Wampanoag*, designed during the height of the American Civil War, by the writer, at that time engineer-in-chief of the United States Navy, and chief of the Bureau of Steam Engineering in the navy department, and constructed under great difficulties and discouragements—moral and physical—additional to those normally belonging to the deranged state of mechanical art at that period, when the industrial resources of the country were much inferior to the demands upon them. No vessel was ever more viciously assailed, and none was ever more triumphantly vindicated.

During the Civil War the United States government had the immense and difficult task of blockading the enormous line of seacoast, extending from the Capes of the Chesapeake to the Sabine river. The wants of the Southern Confederacy were so pressing that supplies, both for military and domestic use, had to be obtained at any money cost, so that "blockade running" speedily became an organised business,—a real profession,—prosecuted in vessels built expressly for the purpose, and operated in concert with a well devised system of signals and other arrangements on shore. The "blockade runners" were without exception British, and neither capital, ingenuity, courage, daring, nor skill were lacking. To foil them required equally high qualities in the United States Navy, and that was its most important service during the war, and it was exceedingly well done.

The purely military exploits of Farragut captivate the public mind, but they really did little or nothing towards determining the final issue, while the prevention of "blockade running"—the invaluable service of the Navy—was of the utmost consequence, as it, by that much, accelerated the exhaustion of the Confederacy. Exhaustion was the determining factor, and not until that was reached could there be the military successes to which the final collapse is attributed by the unreasoning



THE UNITED STATES CRUISER "WAMPANOAG." BUILT IN 1868 FROM DESIGNS BY NAVAL CONSTRUCTOR B. F. DELANO, U. S. N. ENGINES DESIGNED BY CHIEF ENGINEER B. F. ISHERWOOD, U. S. N. THE FASTEST STEAMER IN THE WORLD AT THAT TIME. TRIAL SPEED, 17¾ KNOTS, OR 20.4 STATUTE MILES

(Reprinted from "The Steam Navy of the United States," by kind permission of the author, Frank M. Bennett, P. A. E., U. S. N., and the publishers, Messrs. Warren & Co., Pittsburgh)

public mind which mistakes effects for causes and thinks appearances are realities. After exhaustion had arrived, any strategy was effective, any generalship was successful, and all battles were victories. To understand the truth of these remarks, it is only necessary to contrast the first half with the last half of that great struggle.

The contest between the North and the South was fundamentally due to industrialism, opposite systems of which were in force in each section of the United States. In the South, the system was agricultural, and based on the crudest of negro slave labour; in the North the system was manufacturing or mechanical, and based on engineering in its various and most refined specialties. These opposed systems required opposite legislation; they could not co-exist; and war only precipitated what peace would have accomplished, but much more slowly.

Industrialism, which originated the strife, determined the issue, and the higher form of it firmly planted its feet upon the neck of its lower-form opponent, as has always been the case in the history of the world, and always will continue to be, for the highest development of engineering art and science represents the highest development of physical power. Napoleon called the British a nation of shop-keepers. This was only a half-truth, the whole truth being that they are a nation of mechanics; a fact, also, to which their present ascendency is due, and which must continue until a nation still more mechanical shall arise. The engineering arts which enable men to conquer nature, enable them to also conquer one another, the highest development prevailing.

The really most important service in modern times to be rendered by a navy, is the maintenance of a rigid blockade of the enemy's sea coast. Of course, this is practicable only after the annihilation of the fleets of that enemy, and this is the first part of a naval programme. But if the uses of a navy went no further than this, its victories would be barren; so many hostile ships would disappear from the ocean and that would be all. A really effective blockade dries the springs at their sources, and, by impoverishing a nation, exhausts it more rapidly than any other method can.

That great genius Napoleon, though he had no naval knowledge, knew well the advantages and uses of blockading, only he never had the means to enforce the system. For want of command at sea he tried to substitute blockading by land, and, could he have succeeded with the Milan and Berlin decrees, he would have struck a deadlier blow at Great Britain than he could have done by all the legions that ever marched beneath his eagles. With his usual magnificence of idea and correctness of perception, he sought to close the world against her commerce and manufactures, confident, and with reason, that nothing more was required for her ruin.

Notwithstanding that the "blockade runners" during the American Civil War used, toward the last, specially designed vessels of high speed and light draught of water, and had the advantage of a perfected organisation, yet so efficient was the blockade that the large proportion of the ships captured made the business a losing one, although the profits were so great that one successful voyage in and out paid for three captures. The "blockade runners" had a better speed than the United States naval vessels on a measured-mile smooth-water trial, but they were not faster on a long-continued sea trial,—a very different matter as they often found to their cost. The qualities of the American naval vessels in speed and in everything else were greatly underrated in the silly clamours of an ignorant press.

Although opportunity was given by the United States Navy Department to all who thought they could produce better vessels than those of the navy, and although many made the attempt, none were successful and nearly all of them were dismal failures. From first to last the reliance of the Navy Department was on the vessels designed by its own highly educated and experienced naval constructors and engineers,—a

rather dearly bought experience it is true,—but it was conclusive and there remained no doubt of the fact.

During the height of the war, when the department was pressed to the utmost to maintain the immense blockade of the southern coasts, and to support the army by naval military expeditions, came the appalling knowledge that a coalition had been proposed by France to Great Britain to intervene, to secure the disruption of the American Union and the independence of the Southern Confederacy. Against so formidable a menace, the Navy Department made all the preparation possible. It had built monitors and small iron-clads which might be employed to defend harbours and rivers (they had been constructed to attack them), but it had nothing to oppose to such fleets as a coalition like this could send against the country. The only return attack open to the United States was upon the commercial marine of those nations. That of Great Britain was particularly vulnerable. But the means of making the attack were lacking. Ordinary privateers could not be produced under the circumstances, either in time or in efficiency.

The writer never believed that Great Britain could possibly do so foolish a thing as to comply with the wild proposition of a visionary like Louis Napoleon. Her statesmen knew that the overthrow of the Confederacy, however long it might be postponed, was inevitable,—industrial causes rendered that certain,—that her entire Canadian frontier would be endangered, and could only be temporarily defended, if at all, at a frightful cost, and would eventually be lost forever, and that she would lose not only much of her other commerce, but the entire trade of the United States, which was then the market for half her manufactures, together with the whole carrying trade between the two countries.

Great Britain was making immense sums of money out of the United States, and could not afford to dam the golden stream thus flowing into her pockets. American purchases made from her for government purposes, above what were paid for by American exports to her, and paid in gold, forced that metal to a premium of over 250. Could the manufacturers of the United States themselves have furnished the needed supplies, no approach to this premium could have been made. Consequently, notwithstanding Mr. Gladstone's leaning towards the Confederacy, his sentimental folly was overruled by stronger heads, and Great Britain refused to acknowledge the independence of the Confederacy. Had she done so, her sales of war material to the United States must have stopped. She would have become a neutral. The phenomenal prosperity of Great Britain has not been created by any such short-sighted policies. She leaves sentiment to others and takes the cash to herself, well knowing that money is not only power, but power in its most concentrated form.

Left alone, Louis Napoleon aired his American ambitions by the miserable fiasco of the Mexican invasion. The causes, entirely personal, which led to that, led afterwards to his own hopeless overthrow. Sooner or later that was sure to come; his position rested on militarism instead of industrialism, and he could not survive military defeat. He was the puppet of an army and he fell with it.

But these forecasts could not be depended on, and it was necessary to make provision for the worst. The United States Navy Department had, from the commencement of the war, continued to build vessels of what may be called inherited types. They were, necessarily, of wood; they were made, for excess of strength, much shorter and fuller than was necessary even with wood; and they were furnished with full sail power as though their steam power was never to be used, and it was really made quite auxiliary, or secondary, to the sails. The naval constructors were adepts in the building of this kind of vessel, and, naturally, were reluctant to re-learn their business by the introduction of new types. Mr. Fox, the Assistant Secretary of the Navy, had been formerly a lieutenant in it, and he was

devoted to a naval system such as he had known it. He frequently said that the man who first put a steam engine in a naval vessel ought to have been hanged. He could not comprehend the power and advantages of such a motor, and he pathetically lamented a naval world which had degenerated, in his opinion, from the days of Admiral Benbow.

The writer, from a study of the blockading problem, arrived at the conclusion that for absolute efficiency two lines of intercepting vessels were required,—an inner line reasonably close to the shore, and an outer line at a distance of about 100 miles from the shore,—the inner line to be composed of a sufficient number of vessels of moderate size and speed, and the outer line to be composed of a much smaller number of large vessels with high speed and much endurance. The successful blockade runners could get in by arriving on the coast at night, the distance they had then to go being so small that they could accomplish it even though pursued by much faster vessels, as the latter had not time enough in which to overtake them. When hard pressed, the blockade runners "lightened ship," to increase speed, by throwing their cargoes overboard, and many escaped capture by this sacrifice, but the profits of the venture were lost, and the Confederacy was not benefitted.

The smaller navy vessels,—gunboats, small sloops of war, and "double-enders,"—built by the Navy Department at the commencement of the war, were really very fast and very efficient vessels for the period, and there was not a blockade runner, though built entirely for speed by the best British engineering establishments, that could escape them if the chase could only be continued long enough. The blockade runner had always the advantage of a long start in the race, and he had the choice of time and conditions, and he chose the night.

The result was the construction of a number of vessels,—large sloops of war,—of the *Hassalo* and *Guerrière* type, very efficient, and capable of sustaining speeds, respectively, of 13 and 12 knots under steam alone at sea, speeds exceeding those of the transatlantic liners of that day. They were full ship rigged, and saved their coal for emergencies by going under canvas alone at other times. They were wooden vessels, coppered, and did not lose speed by the fouling of bottoms. They carried a very large quantity of coal in their bunkers, water and provisions for a long time, and they were a very comfortable and efficient class of vessel, with fine nautical qualities. Their machinery, designed by the writer, was simple, strong, compact, economical, always ready, never broke down, and was easily manageable. These vessels could keep the sea indefinitely without coming to anchor.

The writer had succeeded in having the models and proportions of these vessels considerably modified from the accepted naval ideas of the time; but the naval constructors would not go farther, and they had not gone far enough. He was not satisfied, and he proposed to the Navy Department a squadron of vessels, afterwards known as the *Wampanoag* class, the hulls of which were to be designed conformably to his ideas, as well as the machinery. The proposition was agreed to and the vessels were built, the naval constructors disclaiming all responsibility for the results.

These vessels were, in addition to being adapted for outside blockading service, specially designed as "commerce destroyers," and they were also to be able to fight, on at least equal terms, with any naval vessel of their size.* It was also necessary that these vessels should have a higher sustained speed at sea (not measured-mile performance) than any other vessels at that time in either the naval or the merchant service of any nation.

The relations of the United States with Great Britain and with France at that time were so precarious, and the utter inability of the United States to

*This was the first instance in the history of navies where the "commerce destroyer" type of vessel appeared, and both the idea and the vessel embodying it were the inventions of Chief Engineer Isherwood.—THE EDITOR.

place upon the ocean fleets capable of coping with the navies of those nations in any reasonable time was so complete, that no recourse was left but to vessels specially built for preying on their commerce. Such vessels had to be fully rigged with sails because the United States had no stations abroad at which coal could be obtained or refitting could be done.

The vessels had to be able to keep the sea indefinitely, and to maintain their supplies and their small expenditure of coal from the prizes they might take. They were intended to destroy every prize, landing the crews as early as possible. They were to cruise in the great tracks of commerce, and were not intended to bombard towns; nor were they to fight, unless the conditions were such that battle could not be avoided. They were entirely too useful otherwise and too valuable to be risked. They were built for business and not for glory. They were solely to attack the enemy's purse, and to bring him to tears of repentance in that most tender point. Those who threatened the United States were not insensible to such considerations, but, above all, they could not afford to lose the immense sums of money they were making out of the United States during the war; they had read Æsop, and forbore to kill the goose that laid the golden egg.

Although the vessels of the *Wampanoag* class had thus no opportunity to illustrate their programme, that programme was none the less sound, and would, even now, in the event of hostilities with those powers, have to be revived by the United States. The "commerce destroyers" of to-day would have steel hulls, but wood-sheathed and coppered to prevent loss of speed by fouling. They would be full sail rigged and fitted with a single screw. They would be simply reproductions of the *Wampanoag*, on a not very much larger scale, but instead of the guns of her period, would have a few of the largest calibre in use. The improvements in machinery would allow a speed to be attained equal to that of the fastest transatlantic steamers of the present day. A small fleet of such vessels would soon annihilate the commerce of any enemy, however much it might be protected by the comparatively slow, unsheathed, and sailless fighting cruisers of the present fashion, which are compelled to keep within sight of a coal depot and a dry dock. Without the dry dock they go slower and slower as their bottoms become fouler and fouler; and without the coal pile they do not go at all.

Sail power, in certain spheres of action, is still an important, though almost forgotten, naval means for particular circumstances, and especially for small navies unsupported by bases at short intervals apart. The real essentials, more than mere type of vessel, are the highest speed when needed, great endurance always, and a battery which, though it may have to be few in number of guns, shall have them of the very largest calibre possible to make and manage. Such a vessel accepts or declines battle at will, according to the strength of the antagonist, and when it engages, does so at so long a range that any inferior guns, no matter what the number, used against it are wholly ineffective.

These conditions of combat render such a vessel almost as formidable without armour as with it, and the displacement required for the armour can be better disposed of for larger or for more guns, for more speed, or for more coal in bunkers. All that is required from the vessel is a clear deck from fore to aft for the few large guns carried in the open; and all that is required from the machinery is to transport these guns at a speed which renders pursuit unavailing and escape impossible. The *Wampanoag* type of vessel can never become obsolete, though it may be neglected by those who cannot appreciate its possibilities, or are too timid to make a bold attempt to realise them.

The process of embodying these ideas in the first *Wampanoag* was as original as the conception of the vessel. It was done engineering fashion, not naval construction fashion. The writer, having computed approximately the dimensions

required for the vessel to carry the intended weights at the intended draught of water, proceeded to design the machinery complete, with the bunkers arranged in the most convenient manner for the delivery of their coal upon the floors of the fire-rooms. The coal was so distributed that it had to be taken evenly along the space occupied by the machinery whose centre of gravity, including the coal weights, was placed as nearly as possible over the centre of displacement of the hull, so that the consumption of the coal would not change the trim of the vessel.

The engineering department, including machinery and coal bunkers, having been designed, and sufficient additional displacement and space having been calculated and arranged for all the other objects forming the completed vessel, the form of the hull was approximately modelled around the whole so as to just include it. This was probably the first time that a steamship was ever so produced. The writer furnished the length, breadth, depth, draught of water, displacement, and three cross-sections, namely, the greatest immersed transverse section and a transverse section at each end of the machinery.

The modelling of the vessel and the designing of all the remaining details were done by Naval Constructor B. F. Delano, of the Brooklyn Navy Yard, where the vessel was built. He was a most competent man for the purpose in all respects, but he did not approve the design, and had made another and quite different one embodying his own ideas, and had already erected a number of its frames. After much resistance on his part, he consented to do the work according to the general plans furnished him, and most admirably executed his task, and in this he was mainly influenced by his personal friendship for the writer.

The *Wampanoag* had three ship-rigged masts, but no bowsprit, which innovation, made against the opinion of the naval constructors, was to give the bow guns a better direct fire ahead. For a hull having the *Wampanoag's* large proportion of length to breadth and to draught of water, the bowsprit sails were not necessary either for propelling the vessel, or for steering it, or for balancing the other sails. In fact, when on the wind, with all plain sails set, the vessel would keep her course with the slightest touch upon the helm, manœuvering well and sailing fast when dragging the uncoupled screw.

The hull was built of wood and sheathed with copper, the wooden frames being double strapped, or "basketed," with flat irons crossing one another at angles of about 45° and secured to the frames. The steering was done by a balanced metallic rudder. The vessel steered like a pilot boat, and at her highest speed required only two men at the wheel. She had no steering engines. She had four chimneys, and at that time, when one chimney was considered by the sailor officers as a sufficient nuisance, four were exclaimed against as something too hideous for toleration. This was the first appearance of four chimneys, and they were arranged so as not to interfere in the slightest degree with working the sails. Since that time many naval vessels have been fitted with four chimneys without exciting any of the animosity that accompanied the advent of their precursor.

In the *Wampanoag* the highest part of the machinery was over 2 feet below the water surface at 19 feet mean draught, and the whole was thoroughly protected by coal bunkers along its entire extent, both below and above the berth decks. The vessel carried in her bunkers 750 tons of coal, sufficient for five and one-half days' steaming at 16¾ geographical miles per hour, and a distance of 2200 geographical miles. When steaming at sea, at the rate of 11½ geographical miles per hour,—the speed of the fastest transatlantic steamer of that day,—the bunkers contained sufficient coal for seventeen days' continuous steaming, and a distance of 4700 geographical miles.

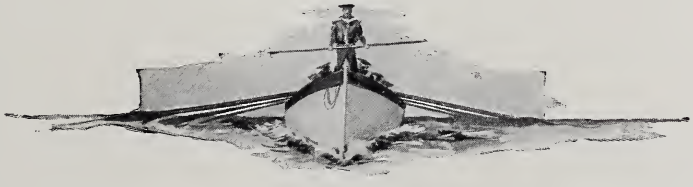
The armament of the *Wampanoag* consisted of one 60-pounder pivot gun, with a bore of 5.3 inches. It weighed 6000 pounds, and its carriage weighed 5000 pounds. There were also two

100-pounder guns, with a bore of 6.4 inches, each of these guns weighing 9700 pounds, and its carriage 1300 pounds. Added to these were ten guns of 8 inches diameter of bore, weighing each 6500 pounds, and the carriages each 1000 pounds; two 24-pounder howitzers, with a bore of 5.8 inches, each weighing 1300 pounds, and each carriage 660 pounds; and two 12-pounder howitzers, with a bore of 4.5 inches, each weighing 800 pounds, and each carriage 500 pounds. The aggregate weights of the guns alone were 94,600 pounds; the aggregate weights of their carriages alone were 19,920 pounds; and the aggregate weights of the ammunition were 106,700 pounds, making a total of 221,220 pounds.

The above weight of ammunition was sufficient for 150 rounds with the 60-pounder pivot gun, and for 100 rounds for each of the other guns. The personnel consisted of 32 officers and 320 men. The machinery complete in the vessel, including boilers and water in boilers and condenser, weighed 1250 tons.

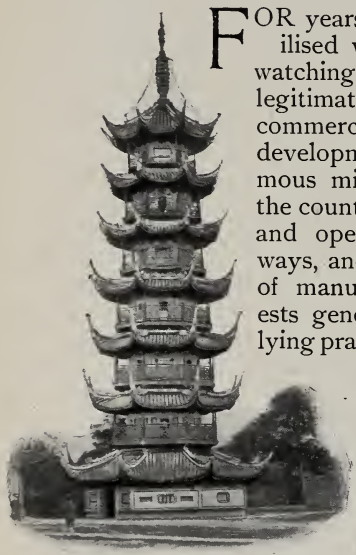
The results of the extended trials made by the engines proved them to develop their power with great economy of fuel. The *Wampanoag* gave, when steaming at the rate of 16.75 geographical miles per hour, an indicated horse-power for 3.12 pounds of mixed semi-bituminous coal and anthracite per hour, according to the official reports made up from her logs and indicator diagrams. The *Ammonoosuc* (duplicate boilers and engines) gave, when steaming at the rate of 17.11 geographical miles per hour, an indicated horse-power, according to the report of her chief engineer, John S. Albert, made to the United States Navy Department, June 24, 1868, for 2.65 pounds of anthracite per hour; and the *Neshaminy*, during the ninety-six consecutive hours' trial at the dock (duplicate boilers and engines), gave an indicated horse-power for 2.80 pounds of anthracite per hour, according to the logs and indicator diagrams forwarded by her chief engineer to the Navy Department. The mean from the three vessels is 2.86 pounds of anthracite consumed per hour per indicated horse-power, an economic result not exceeded by any single-cylinder engine working with the same initial steam pressure.

A Detailed Account of the Hull, Engines, and Boilers of the "Wampanoag," and Tabulated Trial Results will be given in the September Number.



OPENINGS FOR MECHANICAL ENGINEERS IN CHINA

By Lord Charles Beresford



FOR years the whole civilised world has been watching China as its legitimate prey in a wide commercial sense. The development of the enormous mineral wealth of the country, the building and operating of railways, and the expansion of manufacturing interests generally have been lying practically dormant under the restraining influences of Chinese maladministration, as we choose to term it, and now, with the impending dissolution of the Empire, foreshadowed more distinctly by the happenings of the past few months, the long expected opportunities for Western skill and enterprise seem almost within grasping distance. In all that will go on in China the engineer's part will be a prominent one,—the predominating one, in fact,—and the openings that will be afforded to the profession generally have, on many occasions, been topics of interesting discussion.

One of the latest, and, in many respects, most valuable contributions to our knowledge of Chinese possibilities appeared in this magazine in April, 1900, in an article entitled "Engineering in China," written by G. James Morrison, M. Inst. C. E., on the basis of many years' residence in China, and at this time recurrence to it may prove profitable as well as interesting. Another account of what the engineer, and particularly the mechanical engineer, may hope for in that country, was given a few months ago by Lord Charles Beresford in an address delivered, on special invitation, before the Institution of Mechanical Engineers. Lord Beresford, as may be remembered, had at that time just returned from a tour of the world, which had for its more particular object, however, the study of possible British trade extension in the Far East,—practically China, therefore,—and the fruits of the exceptional opportunities which he enjoyed for collecting information were, in part, presented in the paper in question. At the present time, with the breaking-up of China in practical progress, they seem particularly apropos, and are accordingly reproduced in the following pages, with slight modification. The illustrations have been introduced as of possibly additional interest.—THE EDITOR.

Imagine an empire which, with its dependencies, covers an area of over four and a quarter millions of square miles and has a population of nearly four hundred millions of people, and then conceive this vast expanse of territory and this multitude of people still pursuing the arts and industries with the primitive tools, methods, and ideas of two thousand years ago! The vista of untapped possibilities for the modern engineer is seen to be extensive and promising. I propose, in this paper, to divide the principal openings for the mechanical engineer under three heads, and to shortly touch upon each.

I may class them as follows:—

1.—Railways and electrical engineering.

2.—Mining and allied works.

3.—Manufactures.

Under the first of these headings I venture to suggest that the immediate development of China will most rapidly proceed. At the time of my visit to

ALONG THE GRAND CANAL

A GATEWAY IN THE PEKING WALLS

China, in 1899, 317 miles of railway had been completed, 2270 miles were building, 2507 miles were projected, and had been, or were then being, surveyed, and 1070 miles had been projected, but no surveys had yet been made, so that, altogether, in the next few years we ought to see over 6000 miles of track laid, and a new and important department will have been created for the mechanical engineer in running, building, and repairing the locomotives and other rolling stock used by the Chinese and foreign proprietors of these railways. I may mention that the energy, the pluck and the signal abilities of Mr. Claude Kinder have already led to the erection of most extensive works at Tongshan. These works construct all their rolling stock, except locomotives, but were engaged on the first engine ever attempted to be built in China at the time of my visit. Mr. Kinder estimated to be able to build engines at £1600 which would cost £2850 at home (with a twenty-four months delivery). His greatest difficulty is the lack of skilled labour. The engines already running on the Shan Hai Kwan Railway are made by Dubs, of Glasgow, and Baldwin, of America. The American engines are much lighter than the British, but are quite good enough for the work. The idea that skilled native labour is cheap is fallacious, as far as North China is concerned, the native workmen getting about £6 a month.

During the twelve months prior to my visit two locomotive boilers had been replaced and four re-tubed, while five locomotive fire-boxes had been replaced with the assistance of native labour. Mr. Kinder estimated that the 300 miles of rail to Shan Hai Kwan cost for everything, including the admirably fitted workshops at Tongshan, about £6000 a mile. Close by the machinery shops were some cement works, but the machinery there was rusting and doing nothing. The works had been started by Chinese, but owing to their curious inability to undertake mechanical or manufacturing work without European supervision, the works had been a failure. Mr. Kinder told me that the railway alone took 60,000 to 80,000 bar-

rels of cement a year, and there was a great demand for it elsewhere, but the works were now closed.

In addition to the labour difficulty, which can be easily overcome when skilled mechanics realise the advantages offered to them in China, there is also another difficulty to contend with,—the Chinese hatred of the "foreign devil." There was some rioting and ill-feeling at the time of my visit, and two of Mr. Kinder's engineers were fired at, and also badly beaten, at Fungti. As an example of the futility of British methods in China, my attention was drawn to the fact that, instead of at once demanding the punishment of the ringleaders, and the withdrawal of the Chinese Kan Suh troops who were responsible for the outrage, the British authorities summoned a conference of the whole of the foreign ministers, and as a result of their united action two of the offenders were mildly whipped, receiving exactly the same punishment as some coolies who damaged a pump handle and a piece of hose pipe a few weeks before. Mr. Kinder was so dissatisfied with this that he at once withdrew his engineers, and the soldiers, emboldened by the mild treatment awarded to their comrades, proceeded to damage winches and boilers at Pei-ho-tien, and to strip off some copper tubing. The matter was, however, soon afterwards settled and the Kan Suh troops withdrawn.

Railways are the greatest, easiest, and speediest instruments of civilisation, and I look forward with confidence to the benefits which will accrue to China, and to trade and commerce, by the opening of the country in this manner. The mechanical engineer has a great part to play in the near future when Stephenson's "Iron Horse" will penetrate into the "Middle Kingdom."

I have placed electricity under the first heading because I learn from the ordinary channels of information that since my return from China it has been rendered possible for the traveller to go from the railway station to the gates of Peking by electric traction. I, personally, was carried into the city in a mandarin's chair, while my staff rode on Chinese ponies, and, judging by the state of the roads then, it is very creditable to the promoters of the enterprise to have so soon laid and started an electric tramway.

In the European settlements electricity is already used for lighting purposes, and even at Hankow, six hundred miles up the Yangtse River, some of the firms were laying down electrical plants. The abundance and cheapness of coal will render this branch of industry,—electrical engineering,—a very profitable one in a short time. The Chinese of the better class are very fond of luxury after European modes, and I have no doubt that they will be ready consumers of electrical power for lighting and manufacturing purposes. Of course all the plant must, in the first instance, be imported. At Kioto, in Japan, I saw the great electrical plant which, in addition to lighting two-thirds of the town, also supplied the motive power for the city trams, for the pumping machinery at the water works, and for no less than sixty

"COLLARED"

A STREET IN THE "NEW CITY" OF SHANGHAI

different industries in or near Kioto. The electric energy is produced by water power from a fall of 120 feet. The plant is chiefly American, but the Japanese are now beginning to make their own machinery.

Japan and America have had a great advantage over older countries, like Great Britain, in the fact that it is far cheaper to start with the latest products of electrical engineering than to replace steam, gas, and other systems already laid down. The reason I have referred to this, is, that China is in the same happy position as Japan and America, and the electrical engineer will have many openings before him if he will study the immediate needs of the country.

Telegraphs already exist all over China, and are Government property. They are badly managed. I was credibly informed that it is often possible to go from Peking to Tientsin and thence to Shanghai, and to arrive in advance of a telegram you had despatched at starting. By paying treble rates it is possible to get reasonable speed, but the service is very inferior. Telephones exist in some of the settlements, but one manager of a telephone company in China told me that all their copper wire was stolen by the Chinese, so that they had a very inefficient service with steel wire.

The mechanical engineer who has adopted that branch of his profession which has to do with mining machinery, boring machinery, hydraulics, and allied works, will find that there is plenty of scope for him in China. The country is full of minerals; coal, iron, gold, silver, copper, mercury, lead, and salt are all to be found in paying quantities, and only skilled workers and the latest machinery are needed to develop the rich resources of this marvellous country. Labour can be had for mining work at the ordinary coolie pay of about 5½d. a day. The Russians are probably much alive to this important feature in Manchuria, where an Englishman showed me specimens of gold obtained by himself in the interior, and another Englishman who has lived for years in the country told me that Manchuria was a white man's country, very healthy and bracing, and with a climate, soil and resources closely resembling Vancouver. But Manchuria is not the only place where minerals are found. All over China there are great deposits. I need only allude to the marvellous coal fields of Shansi, with seams 80 feet thick, which the Peking Syndicate are about to work; to the resources of Shantung where I have seen a German missionary map marked in all directions with notes of gold, coal, iron, and other materials; also to the coal fields and iron mines of Hanyang and other places on the Yangtse, and the many other districts where minerals have been found to show that the riches of China in this direction are incalculable. All of these vast stores of underground wealth belong to the Chinese government. There is a great field for mechanical engineers in most of the old and all of the newer concessions and settlements, in supplying water to the European community. At a place like Hankow, for instance, where there are no waterworks at all, there is not only the European community, but the Chinese on the other side of the river who would be glad of waterworks. At present all water has to be boiled before use, and is even then unpleasant. There is already a project under way for supplying Canton with water. For mining machinery, engines, pumps and all other plants of this description there is a great demand, and only capital, and capable mechanical engineers are needed to give a great impetus to manufacturers of these goods.

The abundance of coal and iron in China, make it absolutely certain that that country will some day become a great competitor with the rest of the world in the industrial market. But so far from fearing this competition, we should reflect that if we are wise, and take time by the forelock, China will for many years to come be an enormous buyer of machinery and tool steel, while before the necessary reaction can come about, and we begin to feel the effects of her competition, China will have become so rich, that the increased amounts of our products which she will take in one

A PUBLIC FLOGGING

direction will counterbalance our losses elsewhere. There are other points for us to remember:—A poor country can never buy much from other nations. Supply creates demand, despite the seeming paradox, and the volume of trade keeps increasing even if individual industries suffer.

If China is a good customer of our goods now, she will become a better customer still when she has more money to pay for them. She can get this money only by exploiting her minerals, and becoming a manufacturing country with large exports. The richer China becomes, the more she will become a purchasing power. Again, it is an undoubted fact that an increase of supply increases the demand for an article. This arises partly from the increased supply cheapening the cost both to the manufacturer and the consumer. The introduction of machinery although at first opposed by the more ignorant, has thoroughly proved this, especially in the case of Arkwright's invention of the spinning jenny in Great Britain. Another instance of this is the case of all uncivilised races, or races where civilisation has stood still, as in China. A few men only can live, and barely live, on a huge expanse of country if each subsists by the food he himself produces; but if on that same extent of country a number of men congregate and set up machinery and workshops, each becomes a specialist and supplies the whole community with an article which he and a few others alone produce, and the land supports more people than when each person supplied his own necessities. If China becomes a manufacturing country she will undoubtedly hit individual industries of other countries, but as long as the volume of our trade increases we need not fear. Our manufacturers will make money in fresh directions.

I visited a great many mills in China, manufacturing both cotton and silk. In every case I found that the mills under entire Chinese management were complete failures. Their system is to pay high dividends and put nothing aside for depreciation of machinery. The whole place thus goes to rack and ruin, and when the inevitable crash comes it

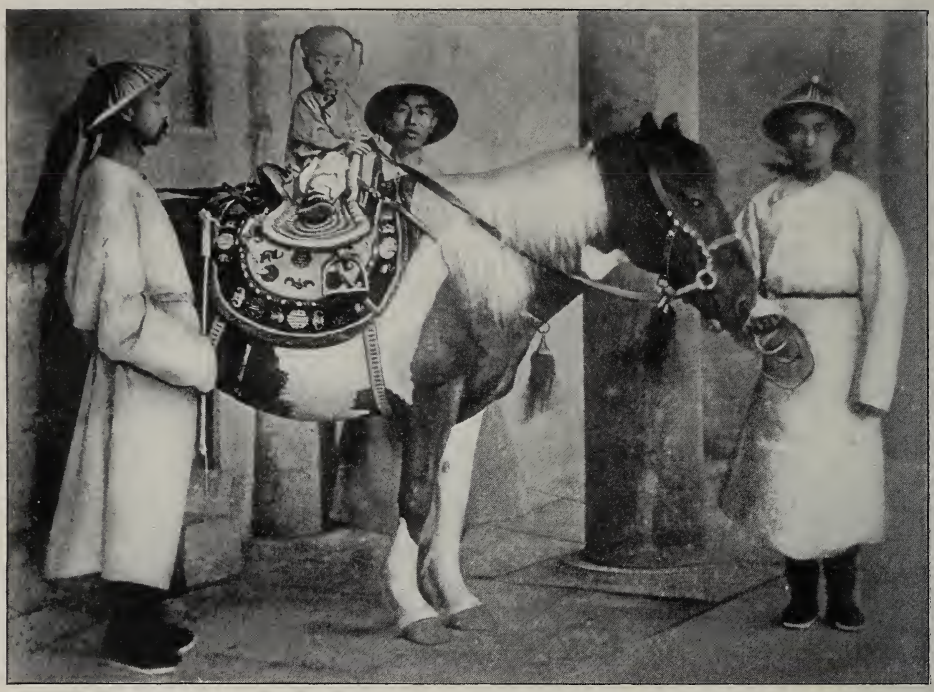
practically means laying down completely new plant. The silk industry is being killed by adhering to old fashioned methods, and the Japanese, by introducing modern machinery are competing to the disadvantage of China's silk trade.

In referring to the openings for mechanical engineers in China, in assisting to establish manufactories with modern machinery, and under European supervision and direction, the native wage is of course an important point to be considered. I found that in South China the current rate of wages for common coolies was 9d. a day; fitters get from 1s. 5d. to 2s. 4d. a day; smiths 1s. 2d. to 2s. 10d. a day; carpenters 11½d. to 1s. 6d. a day; masons 1s. 2d. a day; and mill and refining hands 7d. a day.

Another opening for the mechanical engineer, is to establish himself as an agent for machinery in the foreign settlements and concessions. Over and over again I saw British machinery with the name plates removed and German and Belgian names substituted, or where the name of the British firm was stamped in, it had been covered over by Belgian and German name plates. This was notably the case at the iron mines at Hanyang and at one of the arsenals, where I saw some of Whitworth's tools so treated. I pointed this out to a Chinese merchant, and he explained it by saying that the Chinese usually bought their machinery through local agents in preference to sending abroad for it. These agents he said were more often than not Germans or Belgians, who understood machinery. The advantages of buying locally from an agent were threefold. (1). Quicker delivery, as the machinery was often in stock. (2). No trouble about the rate of exchange increasing the cost after it was ordered. (3). The local agent could be held responsible for defects, and was available for repairs, if anything went wrong. I think this is a very important point for engineering firms and it also offers an opening for young men who are good mechanical engineers to take up the sale of machinery and to push it.

In connection with this matter I wish

IN A CHINESE COURT OF JUSTICE



THE VICEROY OF CHILLI, LI HUNG CHEONG | H. I. C. M. THE EMPEROR KWANG SU | THE EMPEROR'S FATHER AND UNCLE

From an Early Photograph

to draw the attention of engineering firms to the immediate necessity of establishing an exhibition of machinery in China with mechanical engineers to explain and show its capabilities. The Chinese are a very practical race, and if they see what machinery can do they will often buy it. Both the Americans and Germans are already taking steps to provide such exhibitions of their goods.

There is one other point to which I should like to refer before leaving this subject, because, although it concerns the manufacturer of goods more than the mechanical engineer, it also affects the latter who would be benefitted by any change in the state of things to be noted. From various points which were brought to my notice I was satisfied that one of the reasons why the British manufacturer fails to supply what the Chinese really want, and is losing ground against American competition, is the fact that British machinery is so often old and nearly obsolete. The British manufacturer does not write enough off his profits for depreciation of machinery and he does not avail himself of the latest machinery from an idea that it will not pay.

The United States are far ahead of Great Britain in this respect. I recently saw a wire machine in New York which cost £1800 and was consigned to the scrap heap after twelve months, to be replaced by improved machinery. In Great Britain one man controls one block for wire pulling machinery, whereas in the United States one man controls four blocks. The United States workmen get higher wages but their food, clothing and rent are proportionately dearer. In Pittsburg eleven to fourteen kegs of nails are turned out by one man in a day and the man gets 8s. a day wages. In Great Britain only six kegs of nails are produced for 6s. a day. Improved machinery means a larger output for less cost, but it does

not necessarily mean that the workmen suffer. On the contrary, the increased output and reduced cost of production so cheapen the article that the demand increases, and in the end more men are employed than before, and wages are also higher. If Great Britain is to retain her position in China as a trading nation there must be improvements at home which will give fresh openings to the mechanical engineer in Great Britian, and this is equally true of all branches of industry.

In conclusion, and by far the most important point, for the mechanical engineer to deal with in my humble opinion, is the question of learning Chinese. I would invite attention to the immediate necessity of training young mechanical engineers to learn Chinese, which can only be properly done by establishing a school of mechanical engineers at Hong Kong. The official Chinese should be studied, as all well educated Chinese learn this; but for practical purposes, and for conversing with labourers each man must become a specialist in the dialect of the province in which he proposes to work. Americans and Germans are both doing this.

For the benefit of mechanical engineers who are prepared to earn their livelihood in China, and to assist in the opening up of the country which is now going on, I will summarise the points where I think there is the best prospect of immediate openings.

1. *Railways.* For all work in connection with railways the advice of Mr. Kinder, the Engineer in Chief of the Chinese Imperial Railways, should be sought, and applications for employment should be made to the various syndicates financed by the Hong Kong and Shanghai Bank.

A CHINESE JINRIKISHA, THE POPULAR NATIVE CONVEYANCE

2. *Mining Work.* This is being undertaken by the Peking Syndicate, which is the most promising venture at present, and by Mr. Pritchard Morgan's Syndicate which has obtained valuable concessions in the Yangtse Valley. Both of these Syndicates are well supplied at present with civil engineers, but there will doubtless be many openings for mechanical engineers in the near future. Electrical and hydraulic en-

gineers should look out for the prospects of employment by the municipalities in the European settlements, and by large firms.

3. Advertisements in the Anglo-Chinese papers in Tientsin, Shanghai, Hankow and other places should for the present be the best means of securing billets in China for mechanical engineers willing to enter the employment of British or Chinese manufacturing firms.

Finally, until there is better security for life and property, and right of residence in the interior is fully accorded, engineers should be chary of accepting even official Chinese engagements requiring them to permanently reside outside the European settlements, as it is hardly fair for men to go to places where Chinese law does not permit a foreigner to live, and then to complain that their consul, hundreds of miles away, does not protect them.

HOT WATER HEATING IN INDUSTRIAL WORKS

By Alton D. Adams

MANY industrial works generate very large amounts of heat in their power plants. As it is possible to deliver the equivalent of only 10 or 15 per cent. of this heat in the form of mechanical work, the efficient use of the remainder is an important matter. It is usually a prime necessity that power development be regulated by the requirements of the manufacturing processes, and the surplus heat is, therefore, unfortunately often irregular as to the time and amounts of its production. Another impediment to the full and economical utilisation of such heat is the fact that it is given off in two large and entirely independent parts,—in exhaust steam and in waste flue gases. Any complete and satisfactory plan for the utilisation of heat in industrial works must, therefore, combine that given off in these two different bodies, and have sufficient storage capacity to provide for the inequalities of its production.

Two systems of heat distribution claim attention, and it remains to compare advantages for the present case. Heating with exhaust steam has long been practiced, and as much the greater portion of the available heat from power plants is in this steam, good reasons should be shown before it is transferred to hot water. It is well known that the distribution of the power developed in manufacturing plants, as to time, is a variable quantity, and that the requirement for general heating by no means corresponds with the exhaust steam available for it. It is also a fact that the demand for heat begins before, and often continues after, the consumption of mechanical power. While exhaust steam has great heating power per unit of weight, its heat per unit of volume is small, and it is, therefore, a poor agent for heat storage. Thus, one cubic foot of saturated steam at atmospheric pressure weighs 0.038 pound and contains 36.6 heat units above the same weight of water at the same temperature. The irregular rate of production for exhaust steam, its limitation to the time during which power is actually in use, and the great space that would be necessary to store any considerable quantity of it, combine to make it an unsatisfactory agent for general and extensive heating in industrial works. It is, in fact, the general practice in such cases to combine the use of steam directly from the boilers, by means of a reducing valve, with that of the exhaust. This plan involves a heavy demand on the boilers during the early part of the day, to heat up cold rooms and consumes a large amount of boiler steam for heating, though the total production of exhaust steam may be more than the heating

requires could the exhaust be had at the necessary times.

In any system by which the surplus heat of power plants is made available for other purposes, it is desirable that the reaction on power production be as small as possible. The amount of exhaust steam that reaches any part of a heating system depends on the sizes and lengths of the pipes through which the steam must travel and on the pressure that maintains the flow. In large works the other factors are usually such that only moderate pressures, up to about five pounds per square inch, are necessary to force the exhaust steam through the system. Even with such pressures the pipes are a large item for an extensive system of heating by exhaust steam. The pressure necessary for the circulation of exhaust is usually obtained by a corresponding back pressure in the engine cylinder, which operates to reduce the engine power in the ratio that this back pressure bears to the mean effective pressure.

The most usual situation as to the utilisation of exhaust steam is that where a part of it is used to heat the feed-water. For this case, if the heat that appears in the by-products of power development is to be made available for general use, the heating power of the waste flue gases must commonly be combined with that of the remaining steam. So long as the exhaust steam is used as the agent of heat distribution, it does not appear that there is any practicable way in which the heat of the exhaust gases can be applied to the same system. The temperature of the exhaust steam is at least 212 degrees, so that it can absorb heat from the flue gases at only a very slow rate. Moreover, the steam has only a small capacity to absorb heat, unless raised to a very high pressure, which would be prohibitive. To sum up the disadvantages of exhaust steam for heat distribution, it presents no considerable storage capacity, requires a material back pressure on the engine where the system is large, as usually arranged, and is not able, in practice, to absorb the heat of the flue gases.

An examination of a hot water system of heat distribution in connection with power plants will show to what extent it is able to meet the desired conditions as to the storage, distant delivery, and combination of heat. The capacity of water for the storage of heat obviously depends on the temperature to which it may be raised, and its practical value in this particular is also limited by the lowest temperature at which it is available for use. Water may be easily raised to nearly 212 degrees by exhaust steam at the pressure of the air, and the flue gases may be subsequently used to push it materially above this figure if desired. As the flue gases are much hotter than the exhaust steam, though the total heat units which they can give up are only a fraction of those in the steam, it will usually be more convenient, for general heating purposes, to give the circulating water somewhat less than 212 degrees by the exhaust and then to reach or go slightly beyond this figure through the application of flue gases.

While in heat distribution by exhaust steam its minimum temperature is usually 212 degrees, in distribution by hot water the lowest working temperature must be much less than this figure. A limit is soon reached, however, for the reduction in temperature of the circulating water, because of the consequent decrease in the value of radiating surface. Just how low the temperature of the circulating water should be permitted to go depends somewhat on local requirements, but a drop of about 61 degrees from 212 can be permitted in many cases. With this change of temperature, each pound of water gives up 61 heat units, so that one cubic foot of water, weighing 60 pounds at about 212 degrees, offers an available storage capacity of 3660 heat units. A cubic foot of steam at the same temperature and atmospheric pressure was found to have a storage capacity in its latent heat of 36.6 units, or only 1 per cent. of that offered by the hot water of equal bulk.

Considering the amount of exhaust steam that may have its latent heat stored in a given volume of hot water

at 212 degrees, it appears that if the working range of the water temperature goes down to 151 degrees, one cubic foot of water will store the latent heat of 3.79 pounds of steam. From this result it is found that if an engine, developing 300 horse-power, furnishes exhaust steam at the rate of 15 pounds per horse-power-hour beyond the amount required to heat the feed-water, a circular tank, 5 feet in diameter and 12 feet long, will store the heat of the surplus exhaust steam from this engine during two hours of operation. The circulating water used to distribute heat from the power plant in an industrial works is naturally arranged to receive the heat of the exhaust steam in banks of coils, not far from the engine. If the coils are well proportioned, the back pressure in the engine cylinder may be but slightly above or only that of the air, a condition seldom attained where the exhaust steam circulates through the regular heating system.

If the plant to be heated is not very large and its proportions, as to height, are favourable, the circulating water may be moved by gravity, as in the regular hot water heating system. In many cases, however, a pump must be used to circulate the water through the heating system at the desired rate. This pump may be driven by power from the main engine, or by steam, and in either case the additional exhaust is available for the heating system. Such a hot water system may have its pipes extended over a very large works without involving more than a small amount of power to maintain the circulation. The sizes of pipes and the power used for pumping will vary inversely for any case. If the exhaust ordinarily available is not sufficient for heating, comparatively small pipes may be used, as the additional exhaust thereby caused is nearly as good as boiler steam for heating. If the amount of exhaust is ample the hot water pipes should be comparatively large, so that only a little power is required to move the water through them. In many cases the water pipes can, with advantage, be made smaller than those to do the same work in an exhaust steam system. If the entire power of the main engine is wanted for regular work, a steam pump will add nothing to the engine load. The hot water system admits of regulation by a change in the speed of the pump, so that the water, instead of undergoing the usual fall of temperature, circulates more rapidly and radiates heat faster, or less rapidly, with smaller radiation.

Unlike the exhaust steam, hot water from the steam-heated coils readily receives the additional heat from exhaust gases. For this purpose a group of heating pipes, as in the case of the usual economiser, should receive the hot water on its way from the steam coils to the general heating system, these pipes being in the path of the flue gases. If desired, the system may be so arranged that the temperature of the circulating water is raised above 212 degrees. If quite high temperatures are desired for some special purpose, as that of drying, a part of the water heated by the flue gases may be kept separate from the remainder and raised to a higher temperature by the hottest part of the gases.

The facts cited warrant the following conclusions:—If the surplus heat from a steam power plant is to be gathered up and then distributed as wanted, the hot water system is best suited to the purpose. If this surplus heat is desired at distant points of an industrial works, the hot water system will take it there with the least reaction on the main power plant. If the heat of the exhaust gases is to be utilised for general warming, or special drying, either alone or in conjunction with the heat of exhaust steam, hot water is the only practicable agent for the purpose. Finally, in a plant without condensers as much as one-half of the total heating power of the coal burned is available for general purposes in a hot water system, a result beyond what can be reached where steam is the distributing agent. In first cost the hot water system is usually slightly above that for the distribution of exhaust steam.

THE IMPERIAL JAPANESE NAVY

By Rear-Admiral C. C. P. FitzGerald, R. N.

HAVING lately returned from Japan and having had the opportunity of seeing Japanese ships and dockyards, the writer undertook to collect a few facts and figures on the subject of the Japanese Navy, laying them before the Institution of Naval Architects of Great Britain in a paper recently presented before that body.

The rise and development of the Japanese Navy is, probably, without precedent in the world's history. When the writer visited Japan for the first time, in 1858, the navy consisted of some junks, and a few ships which were said to have been built and rigged on the models of Dutch ships of the seventeenth century, and they certainly looked like it. In July, 1858, Her Majesty Queen Victoria presented the Mikado with a small steam yacht of about 400 tons. She was called the *Emperor*, and was presented at Yeddo (Tokio) by Lord Elgin to the Japanese Commissioners deputed by the Shogune to receive her. The Mikado did not make use of her; at that time he was not allowed out. This is believed to have been the first steamship possessed by Japan.

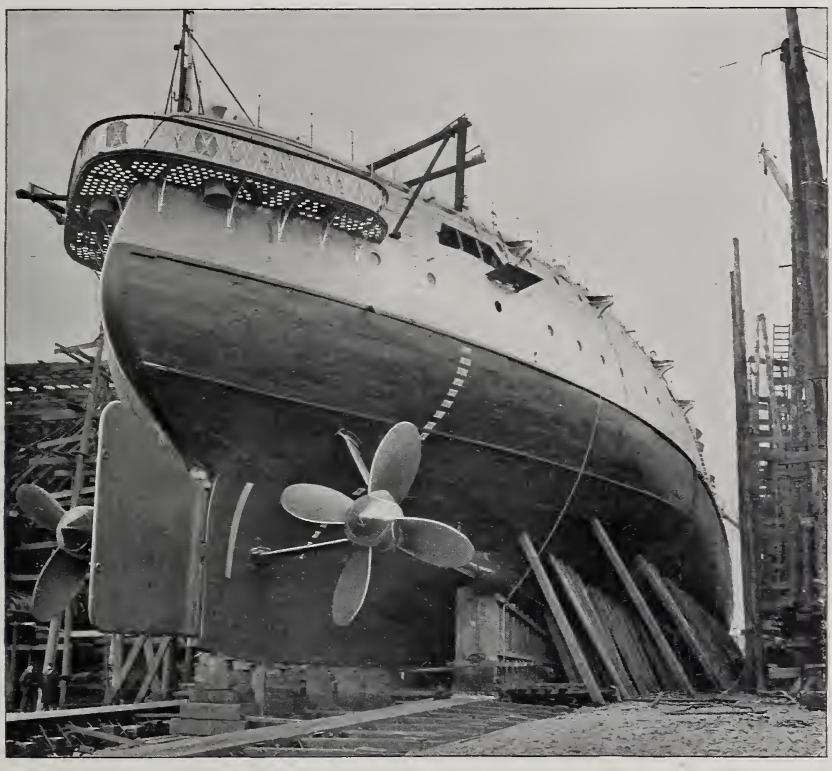
The first real start made by Japan in the production of a modern navy seems to have been the purchase of the ironclad *Stonewall Jackson* from the United States Government in 1866. She was a small ship of only 1300 tons burden, but she carried a 10-ton gun, besides some smaller ones, and was a powerful ship of her day; she was re-named the *Adzuma*. The first ship built in Great Britain for the Japanese Government was the *Foo-So*. She was built at Poplar by Samuda, from designs by Sir Edward Reed, and was launched in April, 1877. She was a broadside central battery ship, barque rigged, 220 feet long, 48 feet beam, 3718 tons, double screw, speed 13 knots, engines by Penn. This ship was followed by the *Kon-go*, *Hi-yei*, and *Rin-jo*, all small ironclads not exceeding 2300 tons, but carrying powerful armaments for their size. There were also about half a dozen unarmoured ships of little fighting value. This was the state of the Japanese Navy in 1880.

Five years later, in 1885, Japan had added only one small ironclad to this list; but there were "built and building" for her several fast and powerful cruisers, armed with Krupp and Armstrong guns. The ironclads, with the exception of the *Foo-So*, were built of wood. In 1890 she had again added only one ironclad to her list, in the shape of an armoured gunboat; but she had by this time provided herself with a considerable squadron of fast and well-armed cruisers, built in various foreign countries. By 1895, although she had not actually added to her list of armoured ships, there were building for her in Great Britain two battleships of the most powerful type, exceeding 12,000 tons displacement, and with a proposed speed of 18 knots. She had also added considerably to her list of fast cruisers. One of these, the *Yoshino*, built at Elswick, had a measured-mile speed of 22.5 knots.

There can be no doubt that the Chino-Japanese war gave an immense impetus to the development of the Japanese Navy. Not only were ships captured

THE FIRST-CLASS BATTLESHIP "ASAHI." BUILT BY MESSRS. JOHN BROWN & CO., CLYDEBANK

from the Chinese, some of which were repaired and are now in commission, but large orders were placed abroad for warships of all classes, including torpedo craft, and the Japanese also set to work to build ships in their own dockyards. At the present time the Japanese Navy stands as follows, eliminating ships which appear to be of insignificant fighting value, but including those which are expected to be ready during the current year:—



THE BATTLESHIP "ASAHI" BEFORE LAUNCHING

BATTLESHIPS

Fuji	Thames Ironworks.
Yashima	Elswick.
Shikishima	Thames Ironworks.
Asahi	John Brown & Co.
Hatsusi	Elswick.
Mikasa	Vickers & Co.

These are first-class battleships in the fullest sense of the term, ranging in tonnage from the 12,300 of the *Yashima* to the 15,000 of the *Asahi*, *Hatsusi*, and *Mikasa*. Their speeds are all at least 18 knots; they are armed with the most powerful modern guns; and considerable areas of their sides are protected by the latest and most up-to-date face-hardened armour. Four of the six carry more armour and more guns than British first-class battleships, but less coal. There is also the *Chinyen* (late *Chin Yuen*), captured from the Chinese, German built. She has been thoroughly repaired, and is now in commission, and, although she cannot be classed as a first-class battleship, being of only 7220 tons, and 14 knots speed, she is a powerful ship of her class.

There are also three small ironclads, —*Fuso*, *Hi-yei* and *Kon-go*,—built in Great Britain in the seventies (before alluded to), and the *Hei Yen*, captured from the Chinese. They are of very small fighting value, and three of them are used as training ships.

Although Japan won the battle of

THE BATTLESHIP "YASHIMA"

Yalu with second-class cruisers fighting against armoured ships, her statesmen are not under the delusion that second-class cruisers will be sufficient to meet the growing needs of their rapidly expanding empire, and they are, therefore, adding to the fleet six very powerful armoured cruisers of about 9800 tons displacement and about 20 knots speed.

The following are all Elswick ships, designed by Mr. Philip Watts. The *Tokiwa* and *Asama* are completed; the *Idzuma* will be delivered about the middle of this year, and the *Iwate* towards the close of it.

	Tons.	Speed.	Armament.
Tokiwa.. *Asama*.. *Idzuma*. *Iwate*...	9750	21.5	Four 8 in., fourteen 6 in., and twelve 12 prs.

The *Adzuma*, of 9436 tons, but the same armament, and 20 knot speed, is building at St. Nazaire, in France, by the Société de la Loire, and is to be ready this year. The *Yakuma*, of 9850 tons, and the same speed and armament as the *Adzuma*, is building at the Vulcan Works, Stettin, Germany.

The above ships constitute a squadron of six extremely powerful vessels, call them what you will, battleships or cruisers; at any rate, not a few of the so-called "naval experts" think such ships are fit to "lie in the line" and take their place amongst battleships. They are at least as powerful vessels as some that are classed as second-class battleships in other navies, and they have a great advantage in speed.

Japan owns another armoured cruiser, the *Chiyoda*, built in Glasgow in 1890, with a nominal speed of 19 knots; she is a small ship of only 2450 tons, and cannot be assigned a very high fighting value at the present day, though she took part in the battle of Yalu.

UNARMOURED CRUISERS, SECOND CLASS

	Tons.	Speed.	Armament.
Chitose	4760	22.5	Two 8 in., ten 4.7, and smaller guns.
Kasagi	4784		
Takasago	4160		

The *Chitose* was built at San Francisco, the *Kasagi* at Philadelphia, and the *Takasago* at Elswick.

**Yoshino*	4150	22.5	Four 6 in., eight 5 in., and smaller guns.

Built at Elswick.

**Akitsushima*	3100	19	Four 6 in., six 5 in., and smaller guns.

Built in Japan.

**Naniwa*... **Takachiho*.	3650	18.7	Two 10 in., six 6 in., and smaller guns.

Built at Elswick in 1885.

We come now to a group of a peculiar type of cruiser, carrying one very heavy gun forward, and a battery of light guns on the main deck aft.

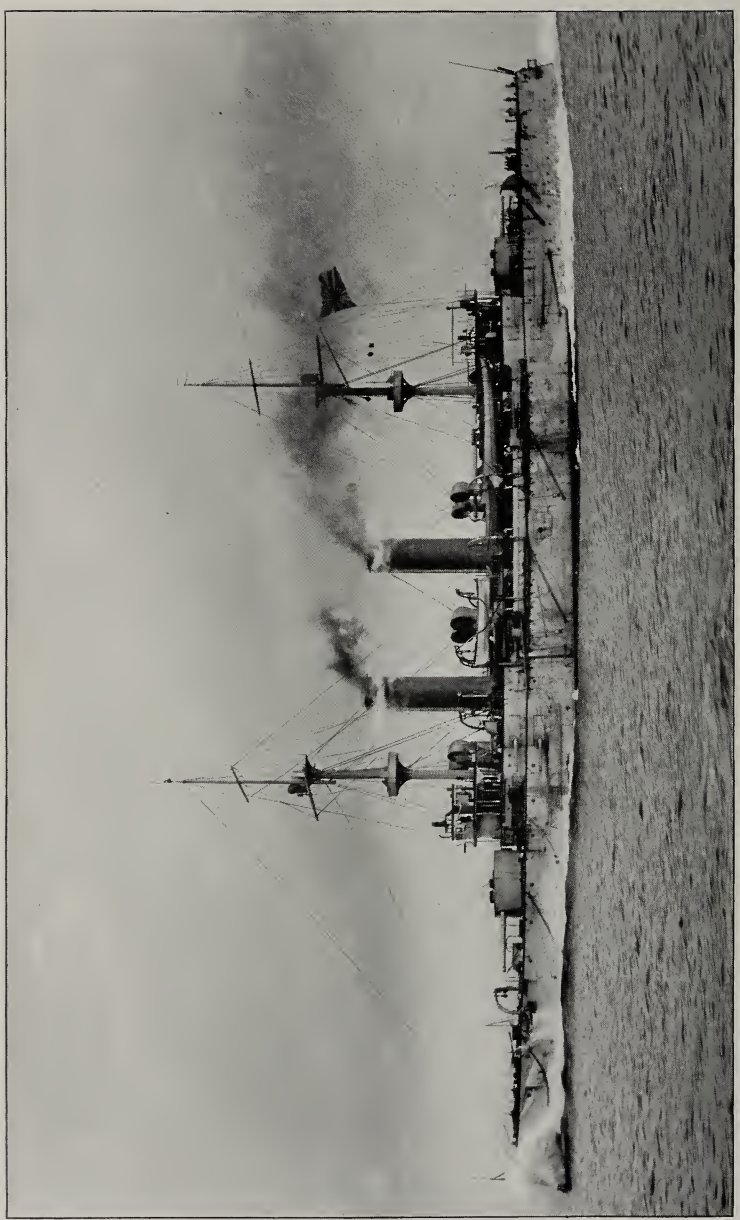
	Tons.	Speed.	Armament.
**Matsushima*. **Itsukushima*. **Hashidate*...	4210	16	One 12 in., eleven 5 in., and sm'ler guns.

* These ships took part in the battle of Yalu.

The first two ships were built in France in 1889: the last was built in Japan two years later. Such an armament appears to be out of place in a cruiser, and a nominal speed of 16 knots to be inadequate. It does not appear that this type is likely to be repeated.

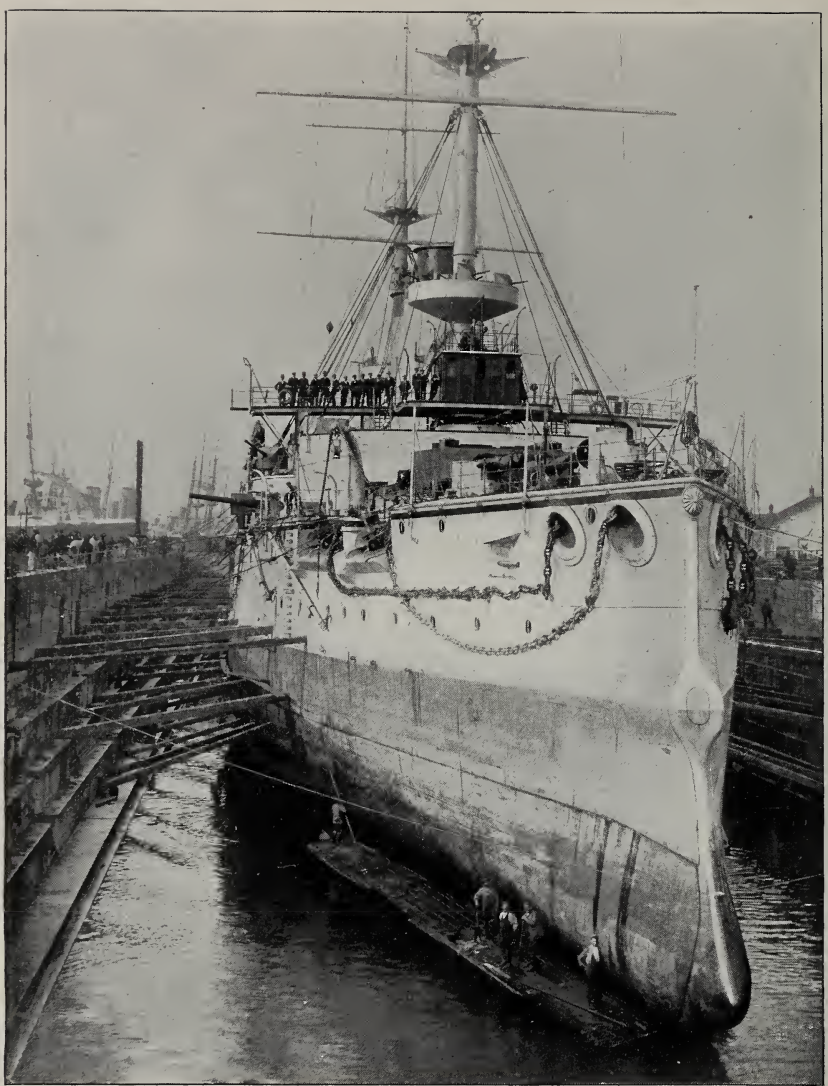
Japan possesses several third-class cruisers of good speed, capable of acting as scouts. She has also a considerable number of small vessels of low speed and but little fighting value, which it would be waste of time to describe. But there are six gunboats of the *Chinto* class, captured from the Chinese, carrying each one 11-inch gun. These might be useful as coast defenders.

The peculiar nature of the Japanese coast line, with its numerous harbours, and the Inland Sea with its archipelago of islands, are physical features in Japan which offer special advantages for the use of torpedo-boats; and she is, therefore, providing herself with a powerful torpedo flotilla of the most modern type of vessels. Messrs. Yarrow, Thornycroft, Normand, and Schichau are all building either torpedo-boats or destroyers for the Japanese Government, and some are also being built in Japan. A torpedo transport on the plan of the British *Vulcan* and the French *Foudre* is projected, but the writer's information does not enable him to state whether the order has actually been placed or not. Messrs. Yarrow & Co., Ltd., have just completed six destroyers of 31 knots speed and upwards, and the same firm has now in course of construction ten first-class torpedo-boats for the Japanese Government. Messrs. Thornycroft & Co. have also just completed six destroyers of about 50 tons less displacement than the Yarrow boats, and with speeds of 30 knots and over. Japan already has in commission, and in reserve, a considerable number of first and second-class torpedo-boats, some of



THE BATTLESHIP "TOKIWA." BUILT BY SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE-ON-TYNE, ENGLAND

THE BATTLESHIP "SHIKISHIMA." BUILT BY THE THAMES IRONWORKS, SHIPBUILDING AND ENGINEERING CO., LTD., BLACKWALL, ENGLAND
FROM A COPYRIGHTED PHOTOGRAPH BY MESSRS. WEST & SON, SOUTHSEA



THE "SHIKISHIMA" IN DRY DOCK

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these being constantly used for exercise.

It is interesting to note that an armour-plated torpedo-boat, named the *Katoka*, 166 feet long, with 19 foot 6 inch beam, built for the Japanese Government by Messrs. Yarrow & Co., Ltd., in 1885, led the torpedo attack both at Port Arthur and Wei-hai-wei. It seems that the Japanese not only know how to order a good article, but to use it when they get it.

There are three Imperial dockyards in Japan,—Yokosuko, Kuré, and Sassebo. They are all capable of being effectually defended. A fourth, Maisuru, on the northwest coast of the main island, is in course of construction. Sassebo can be approached only through narrow and tortuous channels, and, from its natural position, may be considered absolutely unattackable from the sea. Kuré is on the Inland Sea, and its posi-

tion, also, is naturally a very strong one; the islands around it are being strongly fortified, and it will shortly be impregnable to sea attack. It may, moreover, be remarked that, with the powerful torpedo flotilla Japan has already got, and is still further increasing, hostile ships operating in the Inland Sea would be likely to have a bad time.

Yokosuko is in the Gulf of Yeddo, and very favourably placed for defence. The heights around are already fortified, and the works now in progress at the entrance to the gulf will protect not only Yokosuko, but also Tokio and Yokohama, and forbid this large stretch of enclosed water to any hostile squadron. Nagasaki, where there is a private shipbuilding yard that turns out large merchant steamers, and where there is one first and one second-class dock, is being strongly fortified, and from its position it is a place of strategic importance. At Hakodati, in the North Island of Japan, the harbour is being artificially improved, and, although there is no dockyard there, the port is being fortified as a harbour of refuge. This place bears a striking resemblance to Gibraltar. At Oterrani, also in the North Island, extensive harbour works are in progress.

Up to the present the Japanese dock-

THE CRUISER "ASAMA." BUILT BY SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE-ON-TYNE

THE TORPEDO-BOAT DESTROYER "USUGUMO." BUILT BY MESSRS. JOHN I. THORNYCROFT & CO., LONDON

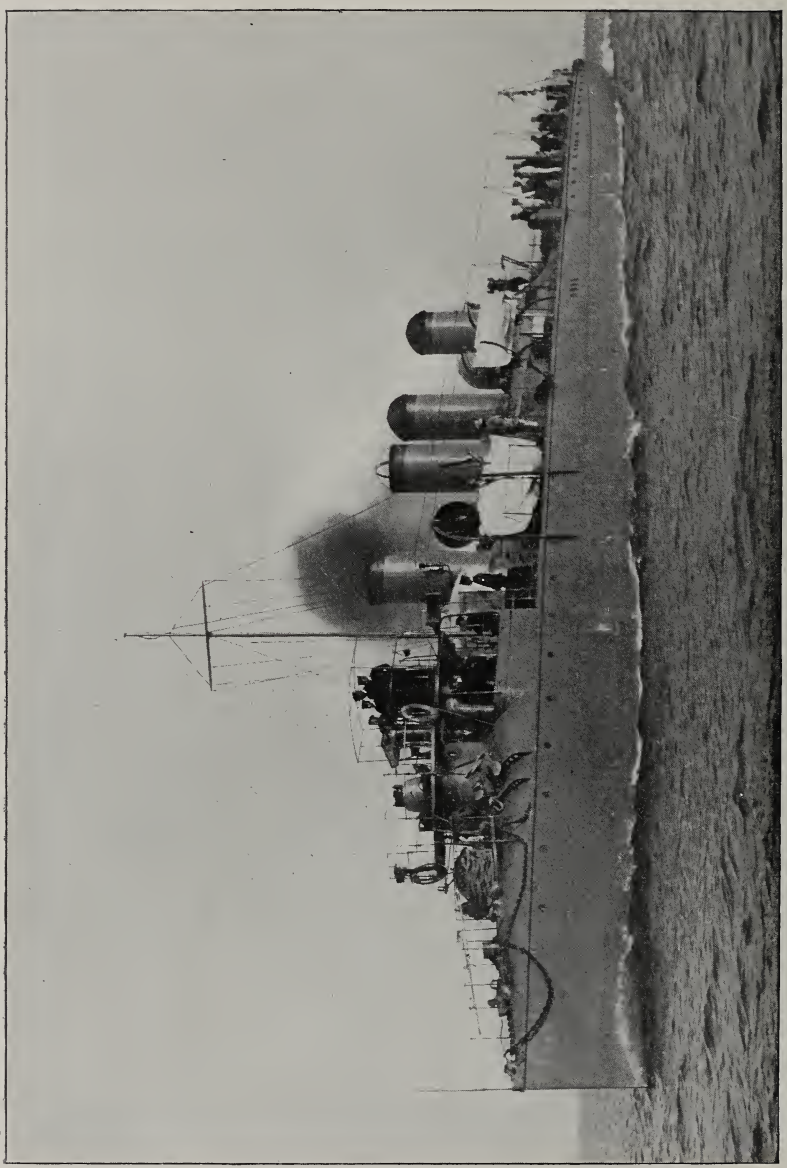
yards have not undertaken to build a battleship, and the largest cruiser they have built is the *Hashidate*, of 4200 tons and 16 knots speed; but they hope soon to be able to build first-class cruisers at Yokosuko, and eventually battleships. At this dockyard there is a first-class modern dock, in which one of the heaviest battleships in the British Navy (the *Victorious*) was lately docked for cleaning purposes, and the writer never saw a similar operation more quickly, more quietly, nor more methodically performed in any British dockyard.

In the *Jiji Shimpo* (Times of Japan), February, 1899, Mr. S. Sassow, chief director of naval construction, writes as follows concerning Yokosuko dockyard:—"This dockyard was established during the Tokugawa regency by the Shogunate in 1866. French officers, comprising naval constructors and engineers (Mons. Verner being the chief director) were engaged, together with a considerable number of leading workmen, for originating the work and for instructing Japanese workmen; several wooden ships have been built here. In 1875 the services of the greater part of the French employees were dispensed with, and the administration passed entirely into our own hands. * * * * We are now building entirely of steel. Our artisans in all branches of shipbuilding and engineering have now attained to a considerable skill. * * * * Hitherto the limit of size at Yokosuko has been 5000 tons; but it is intended to enlarge the dockyard so as to be able to build cruisers of all classes; and in course of time we expect to be able to build battleships. All materials have to be purchased abroad, even for building cruisers."

With regard to steel armour plate manufacture Mr. Sassow says:—"Should such be established in Japan, it would hardly be able to manufacture plates within six years from starting. With the experience of six years even they will probably find that it will be only after many years of further experience they are able to turn out plates of uniform thickness." Under these circumstances, the armour-plate manufacturers of Great Britain need not feel any immediate alarm of dangerous competition from Japan.

It is not proposed to say much concerning the *personnel* of the Japanese Navy, yet a few words on the subject may not be out of place. From the first awakening of Japan her statesmen seem to have grasped the fact that it would be useless to have a modern navy on the European model without having officers and men trained to work it; and, as it takes longer to train men than to build ships, they started at a very early stage to make provision for such training. Not only was the British Admiralty applied to for permission for Japanese officers to serve in British ships,—which was freely granted,—but they were also asked to lend experienced officers to go out to Japan and undertake and organise the systematic training of both officers and men on an adequate scale. Admirals Sir Richard Tracey, Wilson, Douglas, and Ingles are amongst those whose talents and zeal are now reflected in the very high state of efficiency which the officers and men of the Japanese Navy have attained, as instanced by the able manner in which their ships were worked during the whole of the operations in their late war, and the high state of smartness and efficiency in peace time, which latter has come under the writer's own personal observation.

The marvellous power of assimilating new ideas and new methods, entirely foreign to all their national traditions and the practice of centuries, which the Japanese have exhibited during the last few years, is a subject which has frequently been commented upon; but only those who have seen their ships in commission, and visited their dockyards in working hours, can fully realise the significance of the wonderful strides they have made during the comparatively short period which has elapsed since they set to work to create and to maintain a modern navy. Their zeal, their earnestness, their close attention to small but essential details, as well as their power to grasp broad principles, must be seen to be appreciated. It has been said that the Japanese are mere



ONE OF THE SIX 31-KNOT TORPEDO-BOAT DESTROYERS BUILT BY MESSRS. YARROW & CO., LTD., LONDON

imitators, that they can copy European ideas and methods up to a certain point, but that they have no initiative, and that if they ever have to engage in hostilities with a Western naval Power, where unforeseen conditions of strategy and tactics may arise, they will break down under the strain and prove to be unequal to the task. That is not the writer's opinion, and he ventures to predict that when any future disturbance of the peace shall occur in the Far East, Japan will not only have something to say in the matter, but will make her voice heard and respected.

Of the new battleship *Shikishima*, shown on pages 309 and 310, the following data may prove of further interest:—

	Ft.	In.
Length over all	438	0
Length between perpendiculars	400	0
Breadth extreme	75	6
Depth. top of keel to upper deck	45	2½
Draught of water, mean	27	3
Displacement at that draught	14,850	tons.

In general constructive details the *Shikishima* follows the usual methods employed for ships of this class in the British Navy. She is built on the usual bracket frame system with wing passages on each side to be used for holding coal. She has a double bottom amidships, with watertight flats at the ends of the vessel, thus having practically a double bottom from end to end.

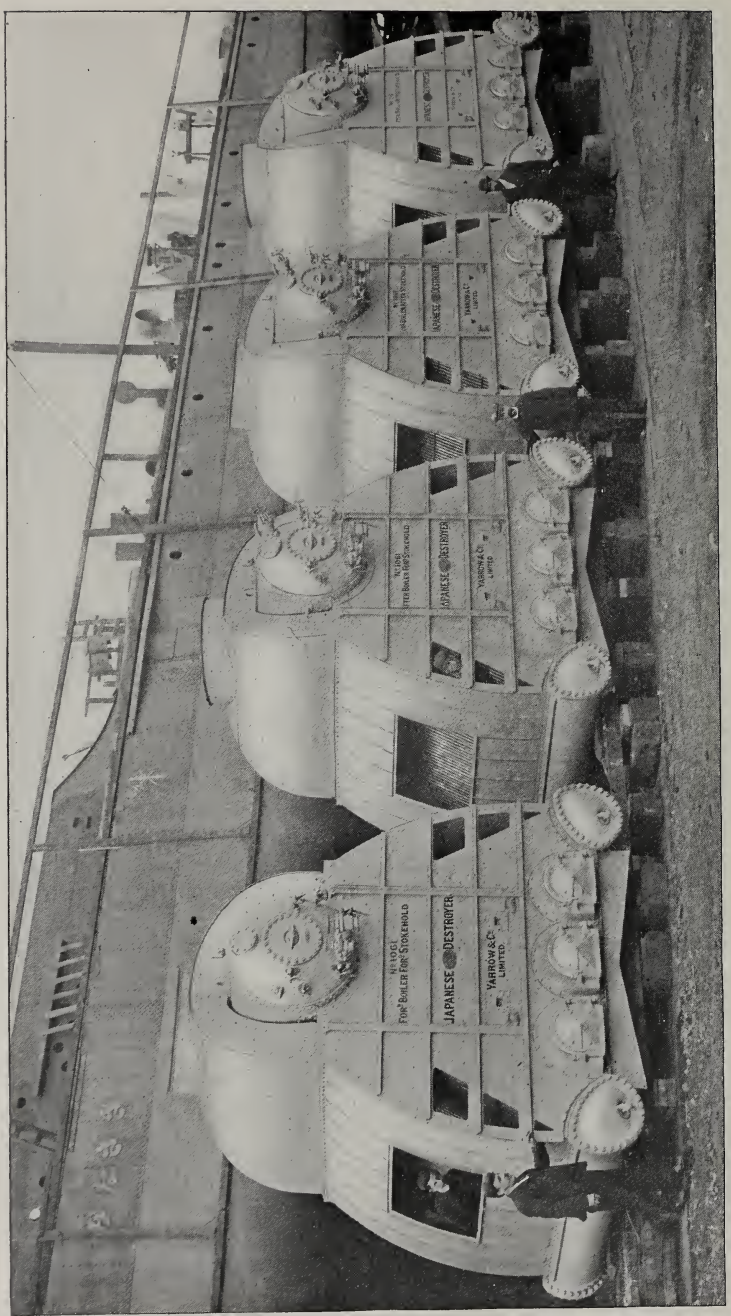
The armour is of Harveyised nickel steel. The side protection consists of a belt which extends from stem to stern. The belt is 8 feet 2 inches in maximum depth, 9 inches thick amidships, and tapers to 4 inches thick at the ends. It has a vertical extension of 5 feet 6 inches below the water-line, and 2 feet 8 inches above at the designed load draught. Above this belt, and carried to the height of the main deck, there is side armour, 6 inches thick for a length of 250 feet, with screen bulkheads at ends, also 6 inches thick, forming a complete armoured citadel, thus extending longitudinally over the space between the two barbettes. Between the armour deck and the belt deck there are 12-inch screen bulkheads, which join the barbettes to the side armour.

The armoured deck is arranged according to the modern principle, as in ships of this class, its sides being joined to the lower edges of the belt. It has sufficient curve to rise 2 feet 8 inches above the water-line amidships. From stem to stern it is 2 inches thick, but an extra plate, 1½ inches thick, is worked on the slope of this deck within the citadel, so that in this part the total thickness of the deck is 3½ inches. The main deck is 1 inch thick within the citadel. The two barbettes are circular in plan, and are placed with their diameters coincident with the fore and aft centre line. The armour on them has a maximum thickness of 14 inches, and runs to a height of 4 feet above the upper deck. There are eight watertight casements on the main deck, and six on the upper deck, all of 6-inch armour on the outside, and having armour plating at the back to protect the guns' crews from explosive shells.

The armament consists of four 12-inch breechloading guns of 40 calibres, two being in each barbette, and fourteen 6-inch quick-firing guns mounted in the casemates referred to. There are also twenty 12-pounder guns, eight 47-millimetre, 3-pounder quick-firing guns, and four 47-millimetre, 2½-pounder quick-firing guns. There are four submerged discharges for 18-inch torpedoes, and one in the stem above the water-line. For defence against torpedoes the usual net arrangement is provided in the design.

Last October she underwent her full-speed trials off Torquay, running an 8-knot course between Dartmouth and Torquay, obtaining a mean speed of 19.027 knots, with 14,667 I. H. P. This speed was beyond the most sanguine expectation, more particularly as the vessel was 1½ inches, or 84 tons, over her load draught, due to more water ballast than should have been taken in, the bad weather making it difficult to get her true draught while out in the open.

In January she left for Japan. She is fitted with Belleville boilers, and with all the latest improvements in steering gear, electric lighting, boat equipment, and other details.



FOUR YARROW WATER-TUBE BOILERS, REPRESENTING 6000 H. P. BUILT FOR THE JAPANESE NAVY BY MESSRS. YARROW & CO., LTD., LONDON

The armoured cruisers *Idzuma* and *Iwate* are very similar in appearance to the armoured cruisers *Asama* and *Tokiwa*. Their dimensions are as follows:—

	Ft.	In.
Length between perpendiculars	400	0
Breadth	68	6
Mean draught	24	3

The normal displacement is 9750 tons. They each carry 600 tons of coal at this normal displacement, the full supply which can be carried in the bunkers being 1550 tons. They have each been provided with triple-expansion engines to develop 14,500 I. H. P., with which it is estimated that a speed exceeding 20¾ knots will be maintained on a prolonged trial. Steam will be generated in twenty-four Belleville boilers of the latest type, with a total heating surface of 35,350 square feet and a grate surface of 1071 square feet. Each vessel will have the following armament: four 8-inch quick-firing guns, twin-mounted, at the middle line on the upper deck, one pair forward, mounted in an armoured gun-house, with armour 8 inches on the front and 6 inches on the sides and rear; and the other pair similarly mounted and protected at the after end of the ship. Fourteen 6-inch quick-firing guns, ten of which will be placed in armoured casemates, and four mounted on the upper deck in the open, protected by strong armoured shields. Twelve 12-pounder quick-firing guns, eight 2½-pounder quick-firing guns, and four 8-inch submerged torpedo tubes. It will be observed that the above-water torpedo tube fitted on the *Asama* and *Tokiwa* has been dispensed with in the armoured cruisers here described.

Each is protected by a belt of Harveyised nickel steel, 7 inches thick, over the main portion of the vessel, tapering to 3½ inches at the ends. This belt is 7 feet wide. Above this belt, up to the height of the main deck, armour, 5 inches thick, is worked along the sides and across the ship in the form of bulkheads, enclosing in this way the bases of the redoubts of the 8-inch guns. A protective deck of mild steel, 2½ inches thick, of the usual form extends from end to end of the ship. The main and lower decks of these ships are made of steel covered with corticene, in order to avoid the risk of damage by fire in action, the upper deck above being covered with teak.

Six torpedo-boat destroyers were built for Japan by Messrs. John I. Thornycroft & Co., of London. Particulars of these are as follows:—

	Ft.	In.
Length	210	0
Beam	19	6
Draught	7	0
Engines	5700 I. H. P.	
Speed	30 knots.	

The vessels are built of steel throughout. The propelling machinery consists of two complete sets of engines of the type invented and patented by Mr. Thornycroft, driving twin-screw propellers, each set having one high-pressure, one intermediate, and two low-pressure cylinders, supported on steel columns somewhat out of the perpendicular, and so arranged that the thrusts of the rods simultaneously act on the cranks from opposite directions in order to obviate vibration in working. In addition to the propelling machinery with condensers, circulating pumps and engines, air and feed pumps, there are fitted the blowing engines, steam steering engine, air compressing machinery, electric light machinery, and distilling machinery.

Three of Mr. Thornycroft's patent water-tube boilers are fitted in each vessel, which give ample steam, and are remarkable efficient in respect of its rapid generation. These boilers are fitted respectively with automatic feed regulating gear, which regulates the supply of feed-water, a steel float fitted in the upper barrel of the boiler automatically opening or closing the valve through which the boiler is filled. Each boiler is capable of being worked independently, and is adapted for a working pressure of 220 pounds per square inch.

The armament of each vessel consists of one 12-pounder, 40-calibre quick-firing gun, and five 57-mm. quick-firing guns; also torpedo gear, consisting of two revolving tubes placed on deck aft, arranged for discharging 18-inch Whitehead torpedoes.

The full complement of each vessel of all ranks is fifty-four men, and the accommodation provided for them is,—One commander's cabin, one ward room, two petty officers' cabins, three compartments for crew. The six Yarrow boats are 10 feet longer, 1 foot more beam, and have about 1 knot more speed than the above.

The Japanese Government, having determined to increase their torpedo-boat flotilla, after considering the various designs submitted, decided upon adopting the one proposed by Messrs. Yarrow & Co., Ltd., of London, and placed an order for ten first-class torpedo-boats with this firm last year. These vessels are 152 feet 6 inches in length by 15 feet 3 inches beam. They are single-screw boats. The contract speed is "not less than 27 knots with a 20-ton load," and a probable speed of 25 knots, with the full load of 44 tons. The vessels are built of mild steel, each being divided into ten compartments, which compartments are devoted to the machinery and crew space, as customary in this class of vessel, there now being little difference in the system adopted by various naval powers as regards the distribution of the load. The turtle deck extends from the bow for some length aft.

There are two boilers of the Yarrow straight-tube type, designd for a working pressure of 220 pounds per square inch, and capable of supplying steam for 2000 I. H. P., with an air pressure in the stokehold of about 1¼ inch. The main propelling engines are of the three-cylinder triple-expansion type, balanced on the Yarrow system, to minimise the vibration. The cylinders are 18 inches, 26 inches, and 39½ inches in diameter, with a stroke of 18 inches, and designed to work up to 400 revolutions per minute. The vessels are lighted throughout by electricity. The coal bunkers hold 32 tons, which is sufficient to take a vessel of this size across the Atlantic, two sister ships having navigated from London to Valparaiso.

The armament consists of one 14-inch Whitehead torpedo tube, built into the bow above the water. One revolving torpedo tube on deck about one-third of the length of the vessel aft of the stem. This tube revolves about an axis in the middle line of the boat, so that the tube can be discharged over either side. A similar 14-inch torpedo tube is provided aft. There is a water-tight torpedo-room under the forward crew space suitable for carrying three reserve torpedo bodies, the warheads being stowed in a separate magazine. The reserve torpedoes are lifted either direct to the bow tube or transferred on a small trolley along a tramway on the deck arranged in such a way that the torpedo can be placed in either of the central tubes. There is a 2½-pounder quick-firing gun right aft with an almost all round radius of fire. The searchlight is placed on the conning tower.

Although the armament above described was adopted after careful consideration by the Japanese authorities, it is by no means the limit for a vessel of this class, a much heavier armament having been carried on five similar boats recently constructed by Yarrow & Co. for the Austrian Navy, *i. e.*, two 18-inch Whitehead torpedo tubes, one on each gunwale abaft the conning tower forward, and one 18-inch torpedo tube aft, two reserve torpedoes in the torpedo-room, and two 47-mm. quick-firing guns, one on each side of the conning tower.

A WORD ON BOILER MAKING

By H. R. Barnhurst

THE enormous increase in the application of power to industrial uses within the last decade, rendered possible by the convenient subdivision and distribution afforded by electric motors, has forced upon the builders of boilers and engines unremitting effort to adapt their products to the conditions imposed. The boiler, as the agency for the conversion of latent power into a living force,—and the engine, the instrument for the further conversion into motion,—still remain as the primal elements in the chain of utilitarianism. It may be that in the future natural forces may be utilised to a greater extent than now; but to-day, for reliability, and cheapness of installation and operation, the boiler and engine hold their own.

It becomes a matter of some interest, therefore, that there be some assurance to the public generally, and to the users especially, that not only shall the engines be satisfactory in economy and regulation, but that the boilers,—those magazines of pent-up forces,—be of such construction that they shall be reasonably safe against destructive explosions. It is at this point that the investigations and experiments of the engineer become valuable. The determination of the qualities that go to make up good boilermakers' plates, rivets, tubes, and braces, and the proportions for the best usefulness of these elements, are becoming daily more clearly known.

It might be thought that all the matters of strength of rivetted seams, and of the plates themselves, have been long enough the subjects of investigation to be household words. But is it so? It has been but a very few years since the shearing strength of a rivet was considered equal to its tensile strength. It is a common thing to hear that boilers are built with a factor of safety of four, five, or six, as the case may be, and to rest content with the statement. Take, for instance, the United States inspection rules, in which a factor of six would seem to be permissible, basing the allowed pressure upon the total strength of the plate. In this case a double-rivetted seam of 70 per cent. of the strength of the solid plate may be allowed a working pressure based upon one-sixth of the solid plate. Here, evidently, the factor has fallen to four and two-tenths, and as, by the rules of inspection, 20 per cent. additional pressure is allowed where holes are drilled and the seam is double-rivetted, the factor of safety really has fallen to three and one-half. Drilling the holes may preserve the plates from the detrimental effects of punching, but it does not increase the strength of the plate section. With the rivetted seam of such pitch that the integrity of the calking may be maintained, the proportion of 70 per cent. will not be much exceeded.

It is a well-known fact that very exhaustive experiments, carried out by one of the prominent boiler insurance and inspection companies, point to the sectional value per square inch of rivet,—in single shear,—as 38,000 pounds. Other experiments have led to the acceptance of 40,000 pounds per square inch of rivet section as a safe working basis.

The substitution of these values for that based upon the tensile strength has led to a complete remodelling of the proportions of the seams of boilers.

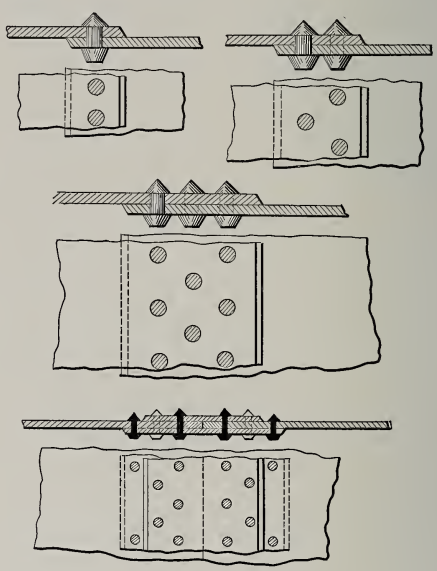
Most of the standard works upon boiler construction contain examples and explanations of various seams and their proper proportions, but rarely are these results tabulated so as to bring within the range of use the commercial sizes obtainable. The insurance companies, indeed, are drawing specifications for boilers in which these proportions are exactly defined, but in the United States the Board of Supervising Inspectors leave these matters to the judgment of the individual inspector.

The writer believes that a set of hard-and-fast rules, covering every ordinary thickness of plate, would be vastly better in results than the methods adopted, and the correct practices thus set forth would be readily accepted as standard by boiler makers everywhere. The fact that the same plates can be tested for high tensile strength, and for high ductility with lower tensile strength, and that apparently satisfactory results can be obtained of different characteristics, is well known to those in charge of testing machines. By conducting tests rapidly the tensile strength appears to be high; another piece of the same metal, tested slowly and given time to flow, will show greater elongation, greater reduction of area, and a marked reduction in tensile strength. One or the other of such results must be misleading. Time is an essential factor in determining the real value of such material, especially when its use is under the conditions of long-continued strain, as in boilers.

In a paper read some time ago by Dr. Huston before the Franklin Institute, of Philadelphia, the remarkable effects of continued overload were strikingly set forth. Plates of a given strength by test were given an additional load each day, until about thirty days from the commencement of the experiment the sample broke at about four-fifths the tensile strength of the original test.

It is somewhat difficult, in conducting tests, to say just where elasticity ends and distortion begins; but the facts are conclusive that the elastic limit is the real limit of safety, and not the tensile strength. If this be conceded, as it must be, and as the elastic limit is, roughly, about one-half the tensile strength, the reputed safety factors of four, five, or six are misleading, and are more nearly correct if put at half that amount.

The common allowance of a working strain of 7500 pounds to the square inch upon boiler braces is, in itself, misleading. The pressure that would produce such a strain upon a brace at right angles to the plate would, in a four-foot



SINGLE, DOUBLE AND TRIPLE RIVETING

brace of 12-inch off-set, produce a strain of about 7700 pounds, due to the angularity of the strain. Then, again, in many cases no deduction from the allowable strain upon the full section is made by reason of the perforation of the brace by rivet holes. There is no doubt, however, that the materials of boiler making are now obtainable of better quality than ever before in the history of the art. The mechanical appliances are more developed and efficient, and the classification and subdivision of labour among the various processes tend to greater perfection in each operation.

It is a fact not true simply of the boiler makers' art, perhaps, that good work is the cheapest. In ordinary par-

lance we often hear this aphorism, indicating a distant reward for excellence; but in boiler work the reward is instant. It does not require great discernment to see that it is cheaper to put rivets into holes that match perfectly than it is to put them into partly blind holes, "faired up" with a reamer or drift pin. It does not take a large slate to figure out the saving in calking and testing closely fayed joints as compared with slack fits. As far as good workmanship goes, the boiler maker is generally alive to its value.

It is a matter of much regret that the severities of several of the noblest trades offer few attractions to most young men. Boiler making is hard work from the beginning; noise and dirt are its personal accessories. It is little to be wondered at, therefore, that so few men among boiler shop workers become experts, not only in the working of the materials, but in grasping the underlying principles of their art, the correct designing, not only of boilers in detail, but of the attached and related parts and settings. The more honour, then, to those whose native faculties and endowments carry them through the hard knocks of the physical work to the higher plane of the mental work.

This, however, is a digression. The purpose of this article is to call attention to the necessity which exists for the adoption and carrying out of correct rules of construction and inspection in land boilers. In most cities minute instructions are issued for sanitary plumbing, and plumbers are licensed by proper authority to work their will upon our real estate; but boiler making and boiler repairs are permitted to any one. It was not long ago that the writer found one of the craft proposing to build a boiler for high pressure by simply using thicker plates and increasing the number of braces. The size and pitch of rivets remained the same as for the lower pressure. The money so spent for extra material would, of course, have been worse than wasted, as it would have bred a confidence of which the result might have been loss of life and property.

But a few days since a newly appointed boiler inspector in a certain district wanted some "pointers" on methods of inspection. He "wasn't up on boilers." It is distressing to think of the results which may accrue from the acts of men so slenderly equipped for their profession. The writer has before him a recent monthly report of the inspections made by the officers of a prominent boiler inspection and insurance company. This recites the detection of cases of bad work in the following items:—

Broken and loose braces and stays	131
Fractured plates	196
Defective riveting	503
Defective heads	51
Defective blow-offs	186
Defective safety valves	123
Defective gauges	231
No pressure gauges	13
Unclassified defects	978

The same report gives a list of twenty-nine explosions of boilers during another month, in which a score or more of men were killed, and others injured. It certainly seems that there should be some escape from this condition of things. But a small percentage of the boilers used are insured or inspected, and it is fair to assume that the percentage of undetected defects will vastly outrun the list above given.

The efforts of various boiler makers' associations are in the right direction, in formulating and publishing specifications of the requisite qualities of plates, braces and rivets. But this is not enough. There is generally no authority behind their recommendations that makes their rules binding and obligatory upon others than the members of the associations.

As a contribution toward correct practice in making good seams in plates such as are in common use, the following tables are printed. They are based upon the use of plates of 60,000 pounds tensile strength, and upon a shearing strain of 38,000 pounds to the square inch, using such sizes and such pitches of rivets as are easily obtainable in daily practice. The strength of the plate sections and rivet sections are very nearly equal, and in the column of bursting pressures the value of the weakest element, be it plate or rivet, is given

as the limit of strength. With these tables the working pressure may be obtained quickly by dividing the bursting pressure by the factor of safety, and by the radius of the boiler.

As an example of the application of these tables, let it be desired to learn the thickness of plate of 60,000 pounds tensile strength per square inch of section proper for a boiler 60 inches in diameter, to be used at a pressure of 140 pounds, with a factor of safety of five. Multiplying the radius 30 by 5 and by 140, gives 21,000 pounds as the least strength of the seam to fill the conditions. A glance at the tables shows that half-inch plate, triple-riveted with 7/8″ rivets, driven in 15-16″ holes of 3½″ pitch, has a strength computed at 21,964 pounds; or 7-16″ plate with double butt-strapped joint, riveted with 11-16″ rivets in ¾″ holes (rivets in outside strap being in double shear 3″ pitch, and in inside strap 6″ pitch), will have a computed strength of 22,968 pounds, in each case amply fulfilling the requirements. Reversing this process, and dividing, in one case, 21,964 by 30 times 5, which equals 150, we have a permissible pressure of 146 pounds, or 22,968 ÷ 150=153 pounds.

The adoption of these practical seams in place of the old rules of thumb, in which a rivet was to be so many times the thickness of the plate and the pitch so many diameters of the rivet, will be found a distinct advance in strength, safety and tightness.

So widespread is the use of boilers, so far-reaching the danger which may be spread by the product of a small shopful of men working ignorantly, that strict rules of construction and inspection, clearly expressed, should be adopted everywhere. Boiler makers should be licensed by boards of examiners, and departures from rules punished by forfeiture.

SINGLE RIVETING.

Plate.	Hole.	Rivet.	Pitch.	Bursting Pressure.
1-4	3-4	11-16	2	8,392
9-32	3-4	11-16	2	8,392
5-16	3-4	11-16	2	8,392
11-32	13-16	3-4	2	9,850
3-8	13-16	3-4	2	9,850
7-16	13-16	3-4	2	9,850
1-2	7-8	13-16	2 1-8	10,753

DOUBLE RIVETING.

Plate.	Hole.	Rivet.	Pitch.	Bursting Pressure.
1-4	3-4	11-16	3	11,190
9-32	3-4	11-16	3	11,190
5-16	13-16	3-4	3	13,134
11-32	7-8	13-16	3	14,607
3-8	15-16	7-8	3 1-4	16,009
7-16	1	15-16	3 1-4	18,173
1-2	1 1-16	1	3 1-4	20,732

TRIPLE RIVETING.

Plate.	Hole.	Rivet.	Pitch.	Bursting Pressure. 73 to 75 %
1-4	5-8	9-16	3	11,655
9-32	11-16	5-8	3	13,007
5-16	11-16	5-8	3	14,106
11-32	3-4	11-16	3 1-4	15,493
3-8	13-16	3-4	3 1-4	16,875
7-16	13-16	3-4	3 3-8	18,459
1-2	15-16	7-8	3 1-2	21,964
9-16	1 1-16	1	3 3-4	24,785
5-8	1 1-8	1 1-16	4	27,272

TRIPLE RIVETING—DOUBLE-STRAPPED BUTT JOINT.

Plate.	Hole.	Rivet.	Pitch.	Bursting Pressure. 84 to 86 %
1-4	11-16	5-8	6	13,281
9-32	11-16	5-8	6	14,941
5-16	11-16	5-8	6	16,601
11-32	11-16	5-8	6	17,531
3-8	11-16	5-8	6	19,740
7-16	3-4	11-16	6	22,968
15-32	13-16	3-4	6 1-2	24,609
1-2	13-16	3-4	6 1-2	25,458
17-32	7-8	13-16	6 7-8	27,918
9-16	7-8	13-16	6 7-8	27,918
5-8	1	15-16	7 5-8	32,582

SOME BRITISH MILLING MACHINES

By Alfred Herbert

THE operation of milling may be broadly defined as the cutting of metals by means of rotary multiple-toothed cutters. The great field of the milling machine is on repetition work, and its introduction has rendered possible the manufacture, on the interchangeable system, of the sewing machine, the rifle, the typewriter, the cycle, and many other mechanical appliances, which, without the milling machine, could have been produced only at such comparatively great cost that they could never have been brought within reach of the multitude. Apart from repetition work, however, the milling machine has, within recent years, made great progress in its application to general work, and the large variety of types and sizes now available enable it to be used successfully and economically in almost every branch of mechanical industry.

From the fineness of the teeth of early milling cutters, it would seem that they were originally looked upon as rotary files and were applied only to the lightest work. Probably the first milling was accomplished on the lathe, the cutters being attached to the spindle or

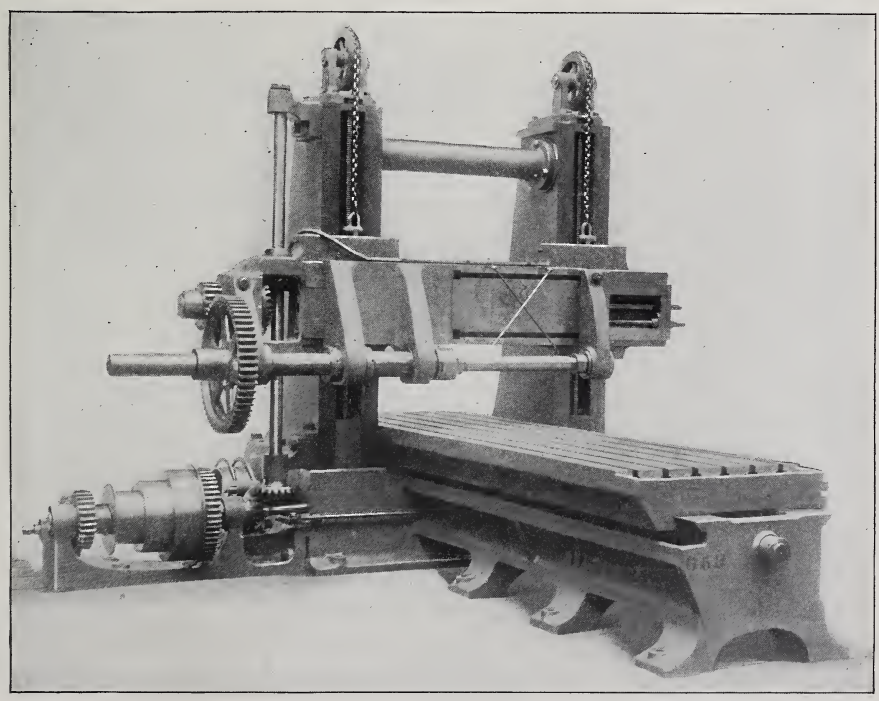


FIG. I. PLANER TYPE MILLING MACHINE, WITH HORIZONTAL SPINDLE. BUILT BY MESSRS. HULSE & CO., MANCHESTER

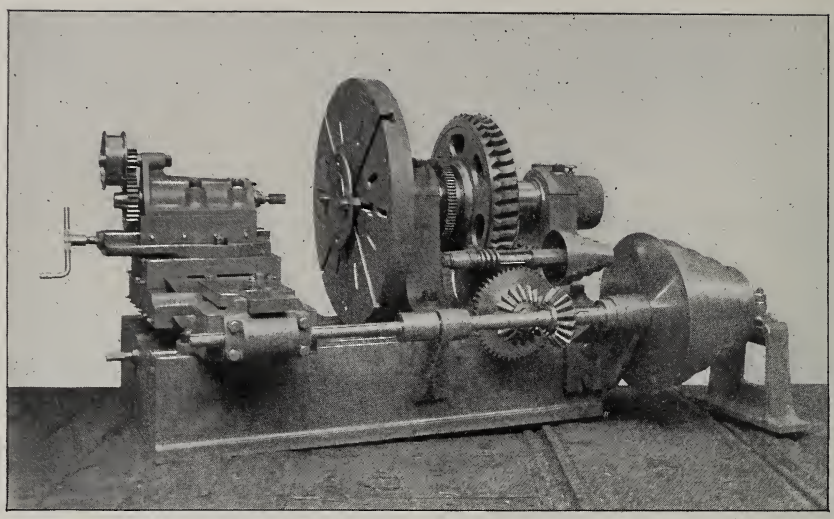


FIG. 2.—A MACHINE FOR MILLING EDGES OF OVAL MANHOLE RINGS. BUILT BY MESSRS. CRAVEN BROS., LTD., MANCHESTER

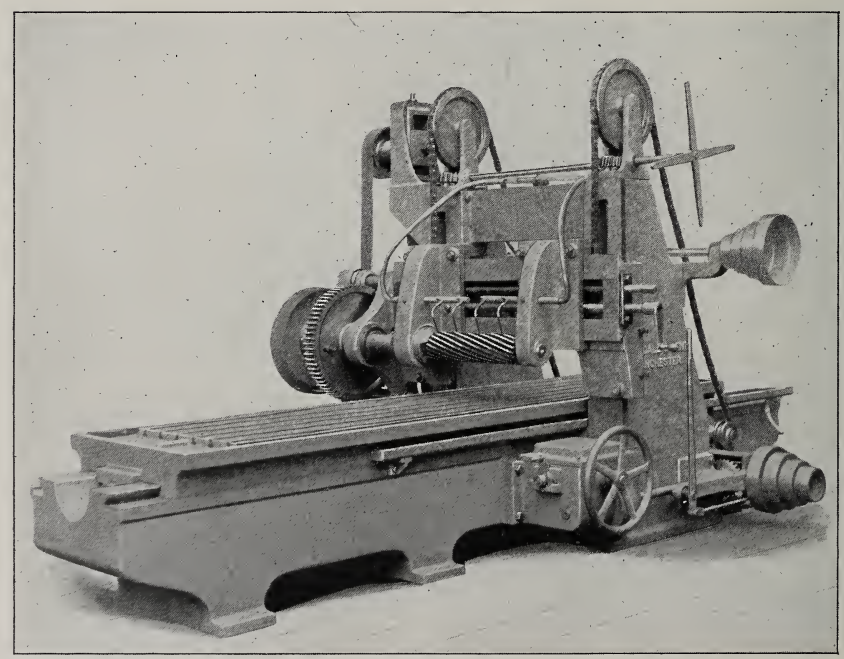


FIG. 3. - PLANER TYPE MACHINE, WITH HORIZONTAL SPINDLE. BUILT BY MESSRS. KENDALL & GENT, MANCHESTER

held between centres, and the work fixed to the slide rest. As the possibilities of milling were realised, special machines were designed for the more convenient use of the rotary cutter, and the constant tendency has been to use coarser and deeper teeth, and deeper and more rapid feeds, necessitating more powerful, heavier, and stiffer machines, and development is still going on in this direction.

The early designers of milling machines were, of course, familiar with the lathe, the planing and shaping machine, and the slotting machine, and it is natural that their designs should, in outline, have borne more or less striking resemblance to one or the other of these tools, much of whose work is now being done on milling machines with a rapidity and economy never anticipated by their originators.

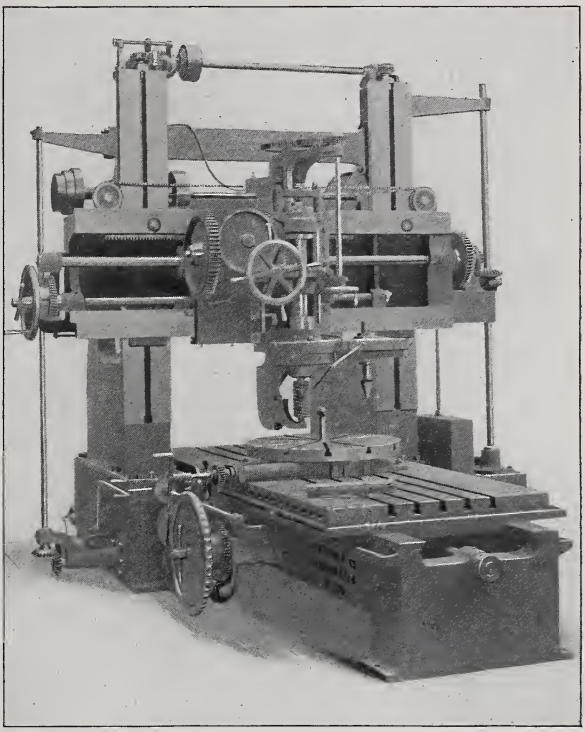


FIG. 4.—PLANER TYPE MACHINE, WITH VERTICAL SPINDLE. BUILT BY MESSRS. WM. MUIR & CO., LTD., MANCHESTER

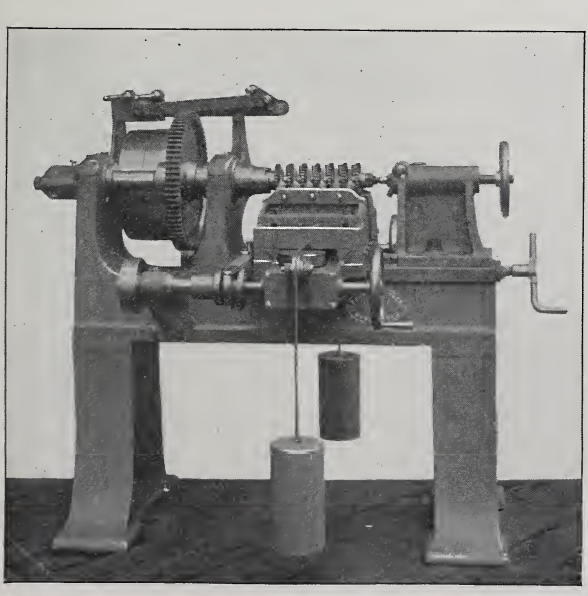


FIG. 5.—A MILLING MACHINE FOR TEXTILE MACHINERY DETAILS, SHOWING THE "LATHE IDEA." BUILT BY MESSRS. CRAVEN BROS., LTD.

One of the most interesting classes of milling machines is that which may be called the "planer" type, from its evident resemblance to the planing machine. This class may be further subdivided into horizontal-spindle and vertical-spindle machines. An excellent example of the former type is shown in Fig. 1, the builders being Messrs. Hulse & Co., of Manchester, who turn out some of the heaviest milling machines in the world. This machine is built in sizes taking up to 6 feet between the housings, and its great depth of table, massive gearing, and general

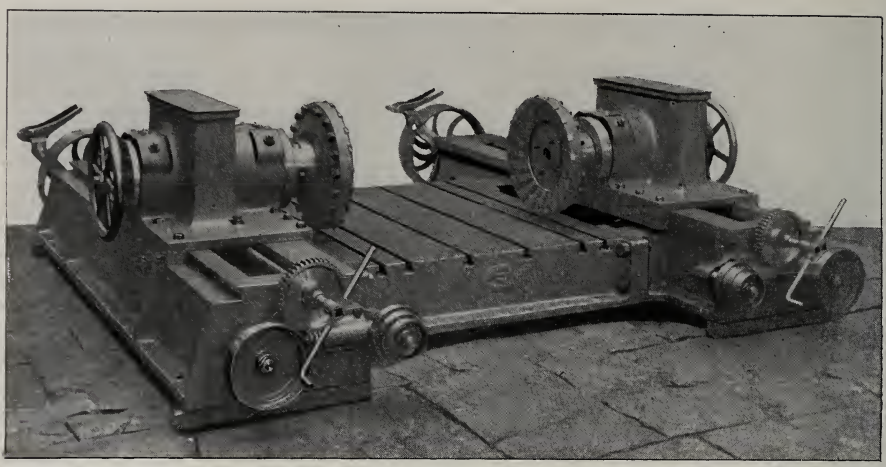


FIG. 6.—SPECIAL MILLING MACHINE FOR FACING THE ENDS OF LOCOMOTIVE STAY BRACKETS. BUILT BY MESSRS. CRAVEN BROS., LTD. MANCHESTER

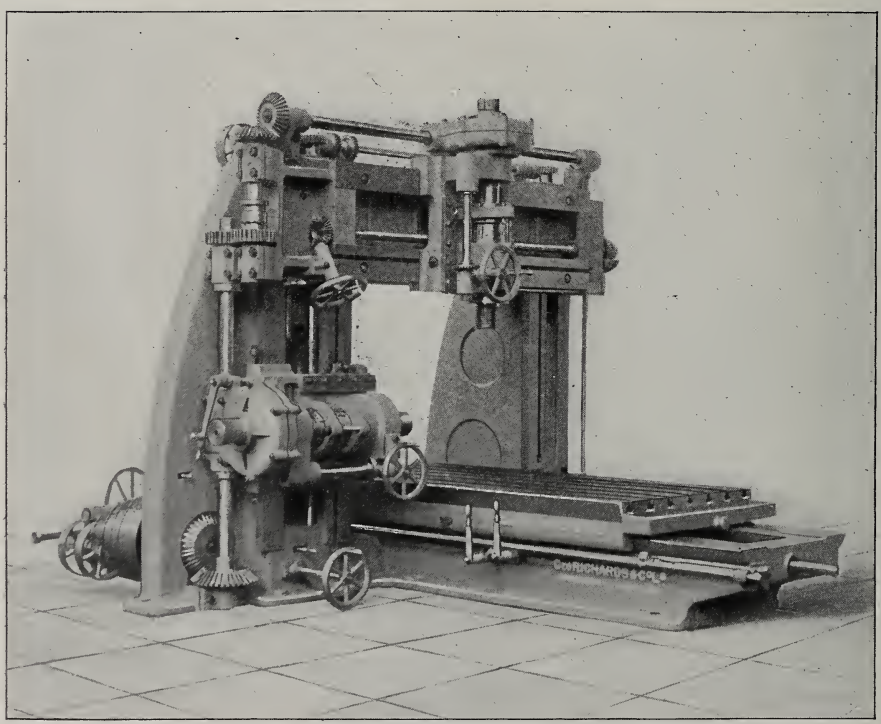
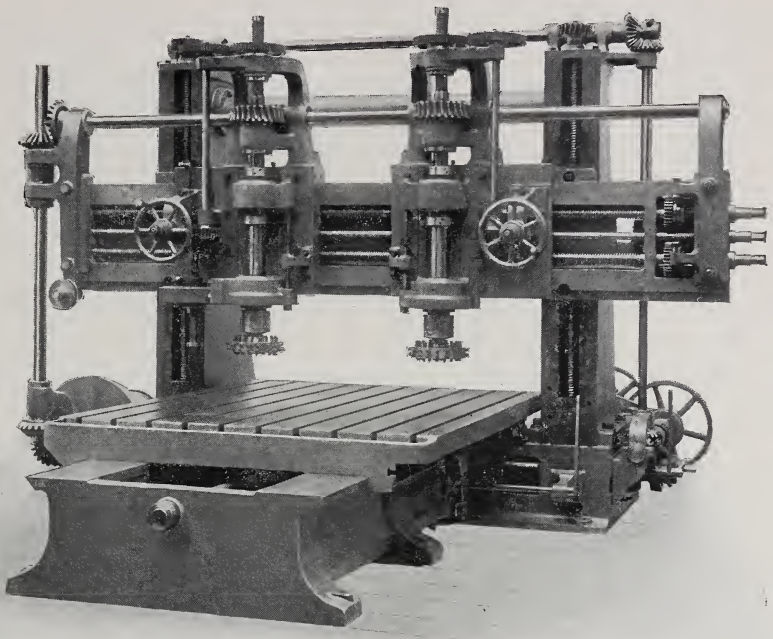


FIG. 7.—A PLANER TYPE MILLING MACHINE, WITH BOTH HORIZONTAL AND VERTICAL SPINDLES. BUILT BY MESSRS. GEO. RICHARDS & CO., LTD., BROADHEATH, MANCHESTER



PIG. 8.—PLANER TYPE MACHINE, WITH TWO VERTICAL SPINDLES. BUILT BY MESSRS. HULSE & CO., MANCHESTER

olidity are evidences that it is built for the heaviest class of work.

Fig. 3 shows a machine of somewhat similar design by Messrs. Kendall & Gent, of Manchester. This is interesting as an example of a system of driving without the use of bevel gearing, the spindle being driven by a belt running over the idler pulleys so arranged that the cross rail, carrying the spindle, may be raised or lowered without disturbing the tension of the driving belt.

The planer type of milling machine with vertical spindle is well illustrated by Fig. 4, showing a tool built by Messrs. William Muir & Co., Ltd., of Manchester. This particular tool is capable of a much varied range of work, dealing not only with flat surfaces, but also with edge milling. The table has self-acting longitudinal feeds in either direction and the saddle also has self-acting feeds in both directions, so that all four sides of a piece of work, as well as its upper surface, can be machined at one setting. Articles of irregular or curved outline, such as locomotive connecting rods, can be profiled in this machine, a copy, or "dummy," of the

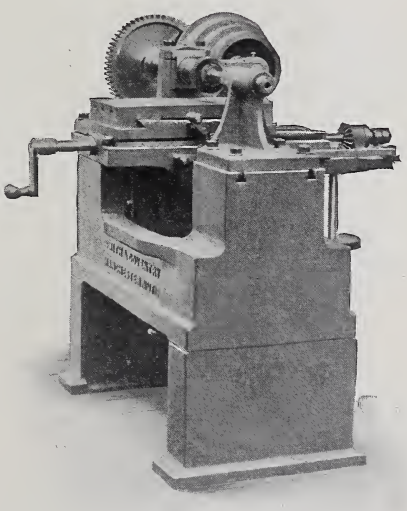


FIG. 9.—MILLING MACHINE, SHOWING THE "LATHE IDEA," WITH ADDITION OF VERTICALLY ADJUSTABLE TABLE. BUILT BY MESSRS. SMITH & COVENTRY, LTD., MANCHESTER

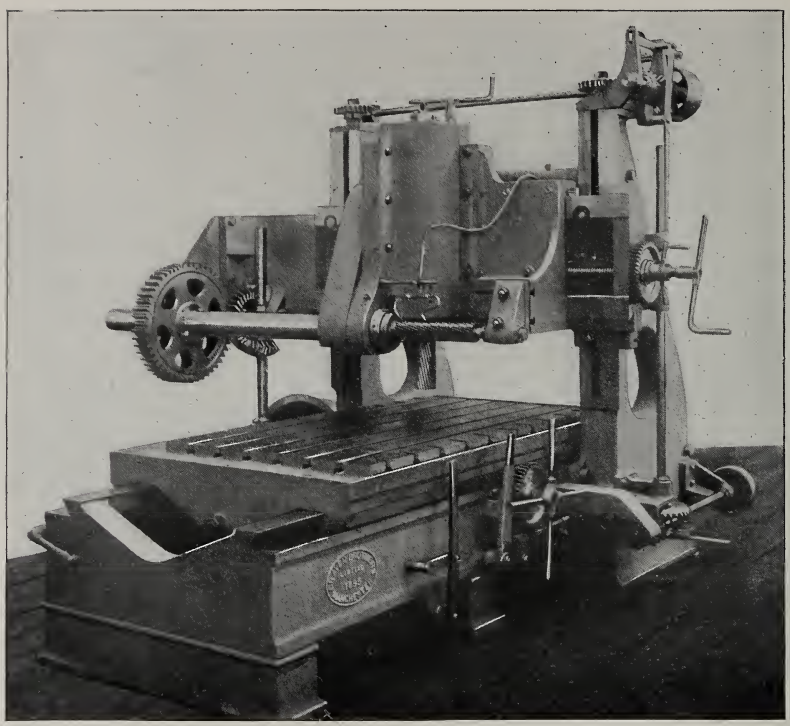


FIG. 10.—PLANER TYPE MACHINE, WITH BOTH HORIZONTAL AND VERTICAL SPINDLES. BUILT BY MESSRS. CRAVEN BROS., LTD., MANCHESTER

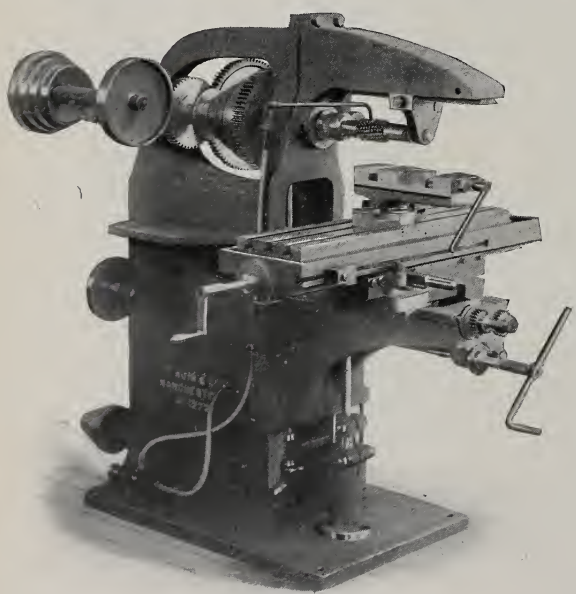


FIG. 11.—HORIZONTAL MACHINE, WITH OVERHANGING ARM. BUILT BY MESSRS. MUIR & CO., LTD., MANCHESTER

desired outline being bolted to the table alongside of the work. The feeler or guide at the right of the spindle is held firmly against the dummy by means of the weight and chain at the right of the machine, and the saddle, being free to move transversely, follows the outline of the dummy and accurately reproduces it on the work. A circular table with automatic feed can also be fitted, as shown, for use in milling circular pieces or pieces having their outline partially composed of arcs of circles, such as the bosses of levers and similar work.

The two-spindle vertical machine shown in Fig. 8, built by Messrs. Hulse & Co., although of considerable size and capable of dealing with work of the most bulky description, is an exceedingly handy tool. The table, in addition to automatic feeds in both

directions, has a quick travel by power for bringing the work rapidly into position. The saddles carrying the spindles have independent automatic feeds in both directions and can be adjusted vertically, either independently by the hand wheels or simultaneously by the central shaft in the cross rail. The manner in which the handles are brought to one side of the machine enables the operator to control all its movements without changing his position, — a very important consideration in a tool of this size. Provision for profiling is also made in this machine.

A machine combining the horizontal and vertical spindle is shown in Fig. 7. This tool is built by Messrs. George Richards & Co., Ltd., of Broadheath, near Manchester. The two spindles may be used independently or simultaneously. The total weight of this machine is over 18 tons, and it is a very pleasing example of modern design. Fig. 10 shows another type of combined horizontal and vertical spindle milling machine, built by Messrs. Craven Brothers, Ltd., of Manchester.

We now come to a class of milling machines which resemble the slotting machine, not only in general appearance, but also in the arrangement of the table and its movements, and in the class of work with which it is intended to deal. Fig. 12 shows a machine of this kind, made by Messrs. Hulse & Co. The spindle runs in a ram of rectangular section, counter-balanced to prevent back lash, and has, in addition to the usual hand adjustment, an automatic vertical feed. The table has automatic longitudinal cross and rotary motions, both hand and automatic, and all of these movements are reversible. It has also a profiling or copying attachment, so that work of the most complicated and irregular shape can be machined.

Another machine of this class, shown in Fig. 13, built by Messrs. Smith & Coventry, Ltd., of Manchester, resembles the foregoing in general arrangement; but it is interesting to note the great differences in detail, both in the method of driving the spindle and feed motions, and also in the table movements. In this machine the variation in the rate of feed is effected, not by the usual cone pulleys, but by an arrangement of friction discs, seen at the right of the illustration. The upper disc revolves at a constant speed, being driven from the main driving shaft by means of a belt and spur gearing. The lower

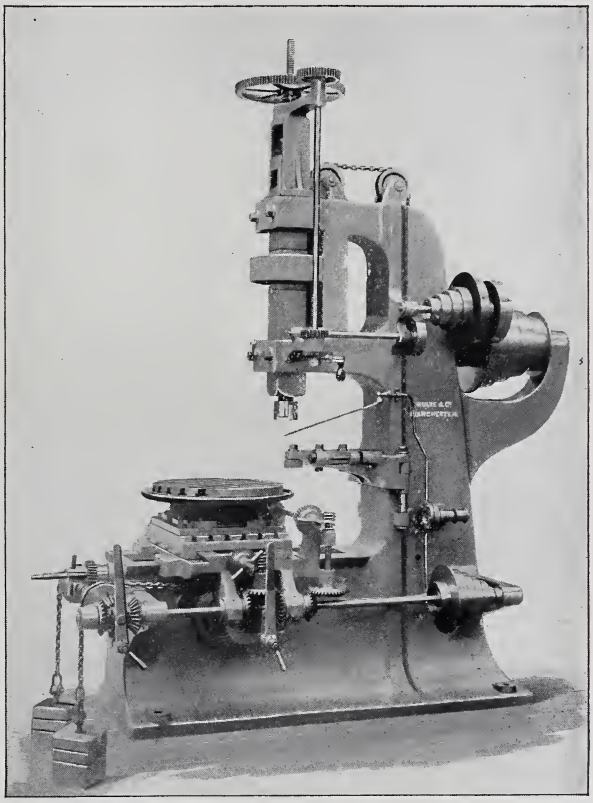


FIG. 12.—A VERTICAL SPINDLE MACHINE, BUILT BY MESSRS. HULSE & CO., MANCHESTER

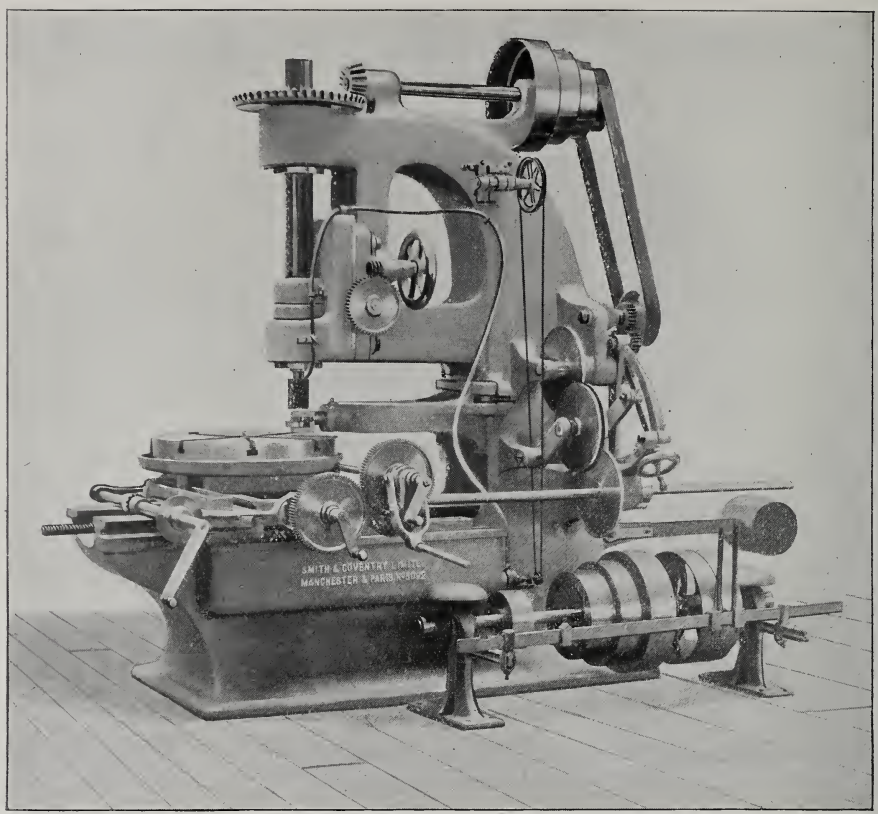


FIG. 13.—A VERTICAL SPINDLE MACHINE. BUILT BY MESSRS. SMITH & COVENTRY, LTD.

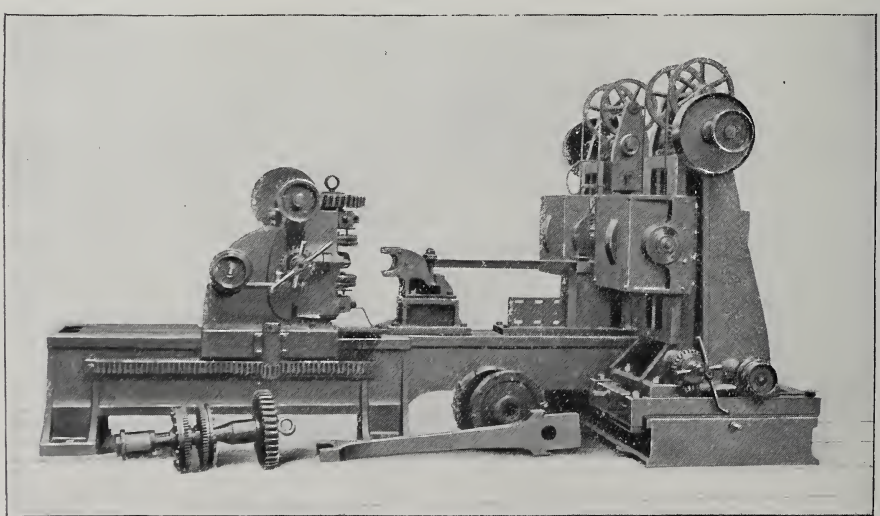


FIG. 14.—MILLING MACHINE FOR FINISHING SIMULTANEOUSLY BOTH ENDS OF LOCOMOTIVE CONNECTING RODS. BUILT BY MESSRS. CRAVEN BROS.

disc is mounted on a horizontal rod which actuates the feed motions of the table. Both upper and lower discs have a raised rim around their periphery. Between these discs a swing-frame is mounted, carrying two other discs which are pressed together by a powerful spring, and which grip between them the raised rims of the upper and lower discs. As this swing-frame is moved upwards by the hand-wheel the speed of the lower disc is increased, and by moving the swing-frame downwards the speed is decreased. By this arrangement any rate of feed between the maximum and minimum is obtained, and the changes are made without marking the work.

Still another example of this type is shown in Fig. 15, turned out by Messrs. Kendall & Gent, and here, again, as in the horizontal milling machine by the same makers (Fig. 3), attention is called to the avoiding of a bevel gear drive, the main belt being carried on idler pulleys to the driving pulley, and back gearing, similar in principle to that of a lathe, being employed. The method of supporting the lower end of the cutter by a removable bracket and bearing is also clearly shown.

A recently designed vertical-spindle milling machine built by the writer's firm, Alfred Herbert, Ltd., of Coventry, is shown in Fig. 16. It will be noticed that the handles controlling the movements of the machine are brought to the front within easy reach of the

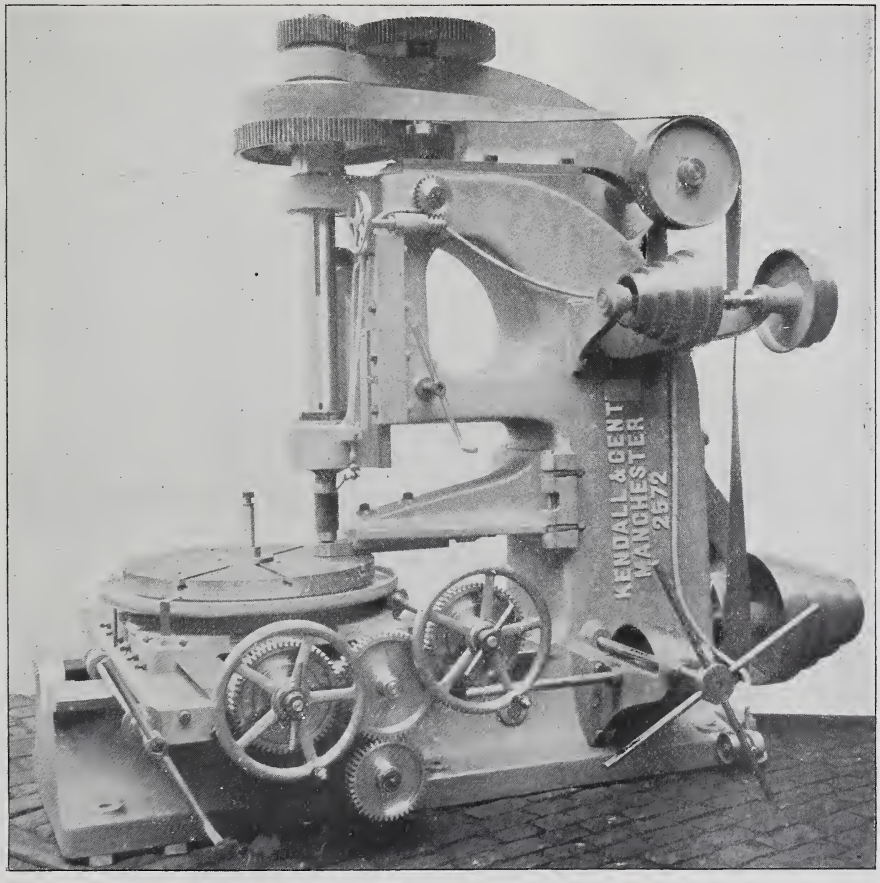


FIG. 15.—A VERTICAL SPINDLE MACHINE. BUILT BY MESSRS. KENDALL & GENT

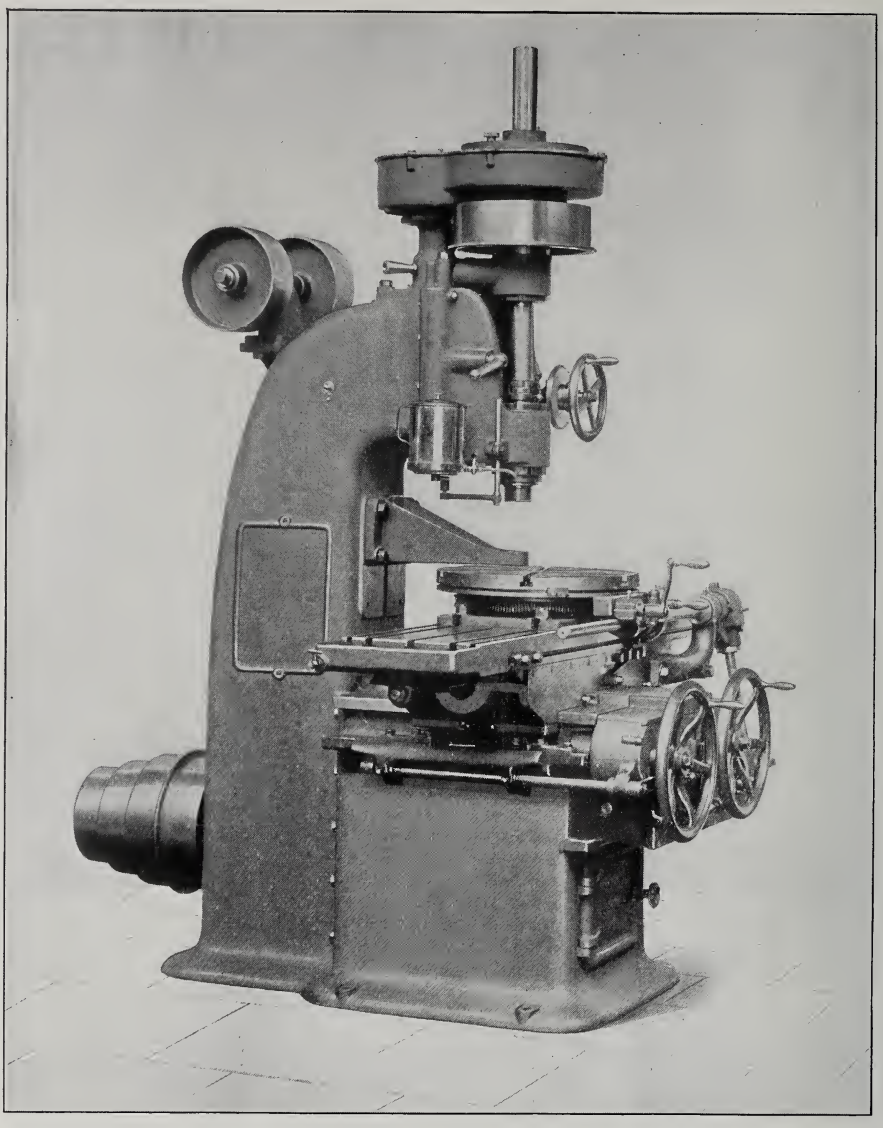


FIG. 16.—A VERTICAL SPINDLE MACHINE. BUILT BY ALFRED HERBERT, LTD., COVENTRY

operator. The machine has automatic longitudinal and cross feeds, both of which are reversible and provided with automatic trips, and also with dead stops. A circular table, with automatic feed in either direction, is also provided. In a much smaller and lighter machine, also built by the writer's firm, the table is mounted on a knee, giving a coarse vertical adjustment in addition to the fine vertical adjustment of the head. The feed motion in this instance is by a leather-covered friction disc and bowl, enabling any rate of feed within the maximum and minimum to be obtained.

We now come to a class of milling machine which appears to have been evolved from the lathe, namely, the regular horizontal milling machine, and for general work of moderate size this type of machine is undoubtedly the most popular. Before dealing with the gen-

eral type of horizontal machine, it may be of interest to examine Figs. 5, 9 and 17, as showing successive steps in the process of evolution from the lathe. Fig. 5 shows a machine, by Messrs. Craven Brothers, Ltd., specially designed for simultaneously milling a number of textile machinery details. Here we have the legs, bed, and fast and loose heads of the lathe almost unchanged; and the work-table itself, though provided with special feed mechanism and work-clamping devices, is, to all intents and purposes, a lathe saddle. The particular work for which this machine was designed did not require a vertical adjustment of the table, and consequently no such adjustment is provided on this machine, though this feature becomes essential on general work. Fig. 9 illustrates a method by which the vertical adjustment of the table is obtained without departing to any great extent from the lathe idea. Here it will be seen that the table is mounted on a knee with a vertical movement, the loose head for supporting the outer end of the cutter arbour still remaining practically unchanged. This machine was built by Messrs. Smith & Coventry Ltd., many years ago, and while of very stiff and convenient construction for repetition work requiring only occasional adjustments, it would not be applicable to general work, as the loose headstock would frequently be in the way of the workman and the work.

A further step in the process of evolution was to do away with the loose headstock and the part of the bed carrying it and to substitute an inverted loose head or arbour support carried on a planed or turned arm projecting from the main casting of the machine. This construction is very well illustrated in Fig. 17, which represents a horizontal milling machine, by Messrs. Greenwood & Batley, Ltd., of Leeds, and in Fig. 11, showing a somewhat similar machine, by Messrs. Muir & Co., Ltd., of Manchester. Fig. 18, showing a horizontal milling machine, by Messrs. Birch & Co., of Salford, Manchester, and Fig. 20, illustrating a horizontal

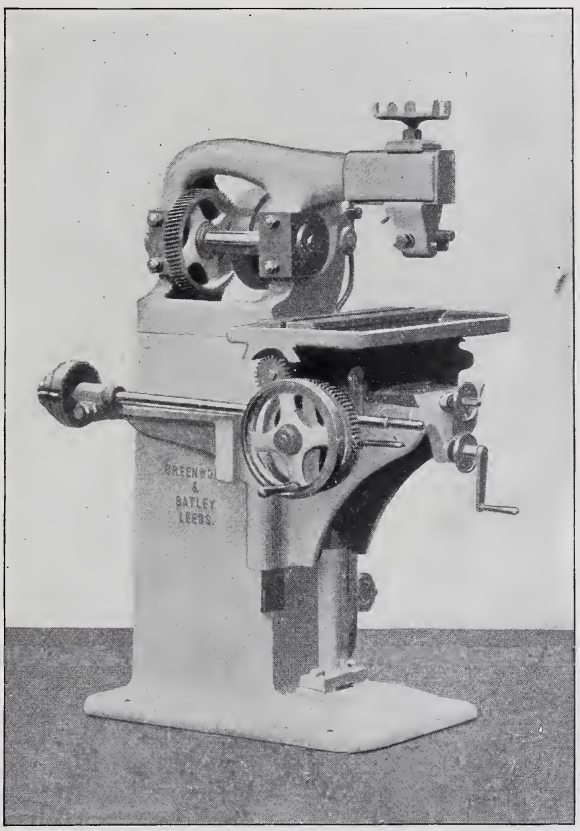


FIG. 17.—HORIZONTAL MACHINE, WITH OVERHANGING ARM CAST SOLID WITH FRAME. BUILT BY MESSRS. GREENWOOD & BATLEY, LTD., LEEDS

machine, by the writer's firm, are other examples of this class, to which also the universal milling machine belongs. Universal milling machines are not built to anything like the same extent in Great Britain as in America, where several firms are devoting themselves almost exclusively to the production of

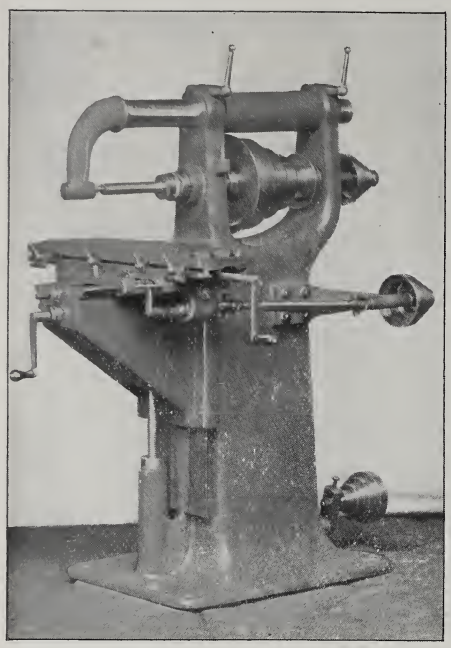


FIG. 18.—HORIZONTAL MILLING MACHINE. BUILT BY MESSRS. G. BIRCH & CO., MANCHESTER

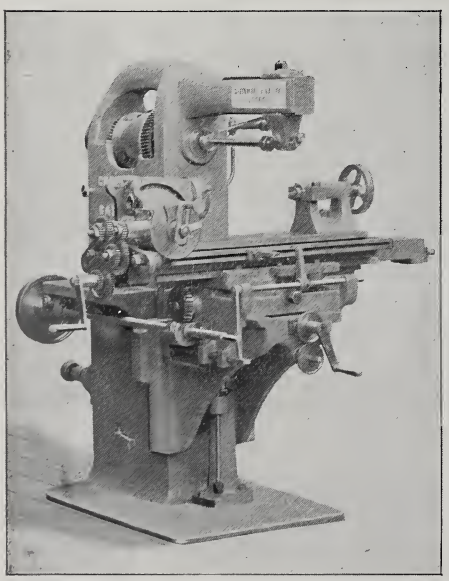


FIG. 19.—UNIVERSAL MILLING MACHINE. BUILT BY MESSRS. GREENWOOD & BATLEY, LTD., LEEDS

these tools. An interesting illustration of a British universal machine, built by Messrs. Greenwood & Batley, Ltd., is shown in Fig. 19.

The machines hitherto dealt with are, in the large majority of instances, general purpose machines, and may be applied to an almost endless variety of operations. In dealing with repetition work, however, it frequently becomes advantageous to employ milling machines specially designed to deal with one particular job, and some illustrations of such machines built by Messrs. Craven Brothers, Ltd., who have had a very wide experience in this class of work, will probably be examined with interest. Fig. 14 shows a special machine for finishing simultaneously both ends of locomotive connecting rods. The rods are clamped in special fixtures, and whilst the two large milling cutters, carried by the rising and falling heads at the right of the engraving, machine the two sides of the big end of the rods, the head at the left of the engraving, carrying a gang of cutters on a vertical spindle, machines the two jaws and also the gap of the fork. Fig. 6 shows a machine for facing the ends of stay brackets for locomotives, the stays being clamped on the slotted bed and the two heavy facing cutters milling off their two ends simultaneously and exactly to gauge. Attention is called to the type of cutter used, consisting of a massive disc with inserted cutters, each independently clamped in position and capable of renewal at small expense when worn or broken. Fig. 2 represents a machine for milling the edges of the oval strengthening rings of man and mud-hole covers for boilers. The plate, roughly sheared to size, is clamped to the face-plate, which is very slowly revolved by worm gearing. The milling cutter is carried on an adjustable slide, which is automatically moved towards and away from the centre, in unison with the rotary movement of the face-plate, the combination of the rotary movement of the work with the reciprocating motion of the cutter producing the oval form required.

One class of milling machine, the

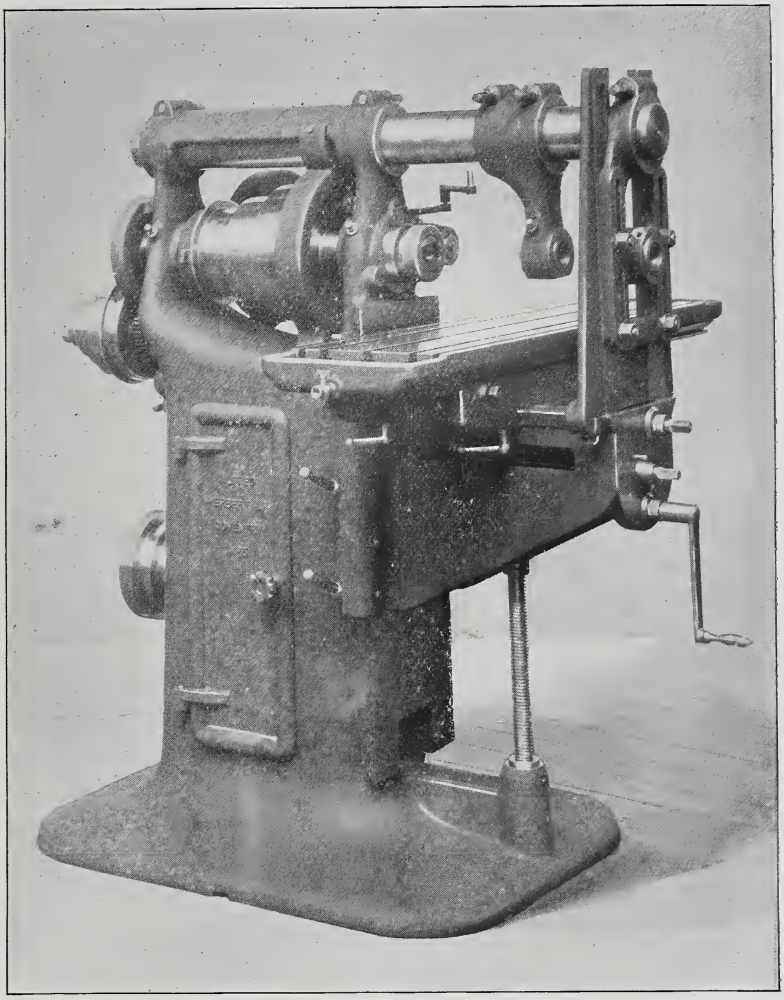


FIG. 20.—A HORIZONTAL MILLING MACHINE, ILLUSTRATING ADJUSTABLE ARM BRACES FOR SUPPORTING OUTER END OF OVERHANGING ARM. BUILT BY ALFRED HERBERT, LTD., COVENTRY

automatic gear-cutter, has been much neglected in Great Britain, and there is no machine built there to-day which will compare with the best American practice in this class of machinery. One reason for this may be found in the fact that the use of machine-cut gearing, long almost universal in the United States, has only recently been developed to any extent in Great Britain, where the impression has for a long time prevailed that cut gearing was a luxury, to be used only in very special instances. Cut gearing is now, however, becoming much more general in Great Britain, and British engineers are beginning to realise that good cut gearing is not only better than good cast gearing, but, given suitable appliances for its production, is considerably cheaper. Bad cast gearing is, undoubtedly, very cheap, but there is not much demand for it. As the greatness of the demand for efficient automatic gear-cutting machinery will become more generally recognised, it is probable that British tool

makers will devote more attention to its manufacture.

The relative efficiency of the milling machine and the planing machine is a subject on which a great deal has been said on both sides. The only general statement on this question that it seems safe to make is, that, as a rule, the milling machine excels on repetition work, and the planer on jobbing work, though there are many exceptions to this rule. Much depends on conditions. Perhaps the work on which the milling machine shows to best advantage is the production, in large quantities, of pieces of complicated section, where the work is held in suitable jigs and the milling is performed by gangs of cutters. On this class of work the milling machine leaves the planer hopelessly behind.

On the other hand, the planer undoubtedly shows to advantage on the machining of large surfaces, particularly when such surfaces require to be subsequently finished by scraping, for, whilst there may be little to choose between the two machines on the roughing cut, the planer, if skilfully handled, undoubtedly beats the milling machine in the finishing when the use of broad tools is understood; moreover, it leaves the surface in much better condition for the scraper.

It must be remembered also that milling machines require costly cutters in considerable numbers if work of a varied nature has to be undertaken, and that these cutters must be kept in good condition by the use of efficient cutter-grinding machines, whilst the planer will deal with an enormous variety of work with tools which are inexpensive to make and easy to keep in order.

On the whole, it seems safe to assume that the future will see a considerably extended use of the milling machine. The tendency of manufacturers is undoubtedly more and more towards specialisation, concentration, and repetition, and it is in this, as previously remarked, that the special value of the milling machine lies.

THE MANUFACTURE OF LIGHT

By John Henderson, D. Sc. F. R. S. E.

PERHAPS one of the oldest of all practical applications of physics has been that concerned with the production of artificial light, and it is strange that, although the problem has been worked at for so many years, it has even now, at the end of the enlightened nineteenth century, received a very unsatisfactory solution. When we compare, say, the great increase in efficiency of the steam engine and dynamo of the present day over that obtained twenty years ago with the increase in efficiency of our sources of artificial light, we are bound to admit that a very small advance has been made. This unsatisfactory state of affairs is due largely to the fact that the true nature of the phenomenon of light itself has been demonstrated by physical science only within very recent years, and a thorough knowledge of the nature of any phenomena to be reproduced must in all cases precede any satisfactory and efficient production of them.

It had long been known that light travels with a velocity vastly greater than could be satisfactorily accounted for on the assumption that it consisted of a stream of material particles, but the real nature of the phenomena presented by light was first indicated by the researches of Huygens, Young, and Fresnel; their work has been continued by others, amongst whom the names of Clerk-Maxwell, Hertz, Kelvin, and Lodge stand out prominently, with the result that now we are in possession of

facts which enable us to satisfactorily account for the production and transmission of light.

Very briefly the modern theory of light may be stated thus:—All matter is built up of exceedingly small particles, and is everywhere surrounded by a medium of which our senses give us no direct information, but which scientific reasoning shows must exist; this medium, which we call the ether, is capable of permeating all substances, its elasticity must be enormous compared with its density, and in many respects it behaves like an incompressible fluid. We also have reason to believe that the particles, of which all matter is composed, are, at ordinary temperatures, in a state of intense vibration, executing many billions of vibrations per second. These vibrations are communicated to the ether surrounding them, thus setting up ether waves which are radiated in all directions. Should the temperature of a substance increase, the rate of vibration of the particles and of the ether waves they produce also increases.

The physiological effects produced by ether waves depend on their frequency; thus, should the rate of vibration lie between 500 and 700 billion per second, they will affect the optic nerve and produce the sensation of light, a vibration frequency at the lower rate corresponding to red light, whilst that at the higher corresponds to violet light, the intermediate colours in the spectrum, indigo, blue, green, yellow, and orange, corresponding to frequencies varying between the two above limits. All vibrations of higher frequency than 700 billion per second are invisible and constitute what is termed ultra-violet light, whilst those slower than 500 billion per second are also invisible and represent radiant heat. It will thus be seen that the problem of producing a satisfactory and efficient artificial light is identical with that of producing ether waves of frequencies varying between 500 billion and 700 billion per second.

The oldest and most common method of setting up ether waves is by the application of heat to substances, for as the temperature rises, the rate of vibration of the particles of the substance increases, and consequently the frequency of the ether waves they set up. Unfortunately, however, it has been found impossible in practice to so heat a substance as to raise the vibration frequencies of all its particles to the visible limits, a very small percentage only vibrating at the higher rates, whilst by far the greater proportion vibrate at rates below 500 billion per second and thus generate invisible waves of radiant heat.

The percentage of the energy radiated as light to the total energy radiated is known as the luminous efficiency of the substance, and the table below represents the luminous efficiencies of various light sources.

Source.	Luminous Efficiency.
	Per cent.
Candle	1.5
Batswing gas burner	1.3
Oil lamp	2.0
Argand gas burner	2.4
Incandescent glow lamp	5.0
Lime light	5-14
Welsbach mantle	13
Arc lamp	13
Magnesium ribbon	13
Electrical discharge in vacua	33
Sunlight	34

One point of importance may be gathered from the above table, namely, that the higher the temperature of the source, the more efficient it becomes as a light source; but even with the best illuminant the efficiency is far from satisfactory.

The above table of efficiencies refers only to the conversion into light of the energy supplied to the lamp; if, however, we calculate the efficiency with reference to the ultimate source of our energy, viz., coal, we get what may be termed the commercial efficiency. In order to calculate this quantity, the following data are assumed:—(1.) That 1 pound of coal contains 11,000,000 foot-pounds of energy, and can yield about 4 cubic feet of gas at the lamp, representing 2,000,000 foot-pounds of energy, or an efficiency of about 18 per cent.; and (2) that the combined efficiency of a boiler, engine, and dynamo is 10 per cent. The following table represents the commercial efficiencies:—

Source.	Commercial Efficiency. Per cent.
Batwing burner	0.23
Argand burner	0.43
Incandescent glow lamp	0.5
Welsbach mantle	2.3
Arc lamp	1.3

Hence, under the best conditions obtaining at present we may say that, out of every 100 tons of coal delivered at gas works or electric light stations, something like 98 tons are, as far as the production of light is concerned, absolutely wasted, and go to produce useless heat. When one considers the enormous quantity of coal used annually for the production of artificial illumination, the absolute waste of 98 per cent. of it seems little short of criminal.

Will the problem ever be solved? It must be confessed that at present the prospects are far from being bright. Some means must be found of exciting ether vibrations between the visible limits only, and of eliminating the slow, radiant heat waves. Whatever method may be eventually employed, it is interesting to note that already, on a small scale, the problem has been solved by the firefly, the most delicate measurements having failed to detect any radiant heat in the light emitted by this little creature. Surely this ought to be an interesting subject for investigation by the physiological chemist, who, working in conjunction with the physicist, might enable us to get nearer the solution of this important question.

Current Topics

In connection with the matter of electrolytic corrosion of underground gas and water pipes and other metal work, due to stray electric railway currents, it is worth noting that in the city of Brooklyn, the sister city of the American metropolis, where the electric trolley reigns supreme, there has, up to this time, been no case of cast iron water-main corrosion, although many cases of seriously affected wrought iron service pipes have occurred. In the 755 miles of cast iron gas mains no trouble was observed until within a year, and then in but two cases. Here again, however, the wrought iron service connections and their malleable iron and brass fittings suffered severely, thirty-eight of such connections on one short length of main having been completely destroyed within three years. The apparent immunity of the cast iron was at first thought to be due to a peculiar chemical composition of the special kinds of iron of which the mains were made, and in order to experimentally test the matter samples of both gas and water mains were used as anodes in various electrolytic cells. In these experiments, as told by Mr. Samuel Sheldon in a paper

recently presented before the American Institute of Electrical Engineers, the electrolytes consisted of samples of earth from various parts of the city, moistened, in some cases, with distilled water, and in other cases with hydrant water or salt water. These cells were subjected to voltages of various magnitudes. In every case the anode was corroded, showing apparently that there is no immunity because of chemical constitution.

In preparing some experiments to determine whether or not the apparent immunity of cast iron mains was due to occluded gases in the pores of the rough exterior of the pipes and of sufficient magnitude to prevent the sending of any considerable current by the stray voltages, the true cause of immunity was discovered. In the casting of pipes in sand moulds, the hot iron unites with a layer of the sand to form a silicious compound which forms a thin coating over the surface of the completed pipe. This coating is extremely thin, and is a non-conductor of electricity. It is not continuous, but contains perforations in many places. If a piece of pipe be covered with insulating paint, exposing only the rough sand-pocked exterior surface, and if it be made an anode in an electrolytic solution, much less current will flow through the solution under a given impressed voltage than under similar conditions with an anode exposing a filed surface of equal area. In some cases, no current at all will pass until the impressed voltage rises to a certain minimum value. If, however, a current be made to pass for a few moments under a moderately high impressed voltage, the rough sand-pocked surface becomes conducting throughout. The existence of a perforated skin can also be shown by endeavouring to close a circuit, which contains a current-indicating device, by means of a wire on the sand-pocked surface. The end of the wire may be rubbed around in many places before there is any indication of a closed circuit. Then, again, a spot will be found where the circuit is closed, and there is no indication of resistance of any magnitude at the point of contact.

The waste of fuel supposed to result from raising steam in lime-encrusted boilers has been made the subject of many a paragraph in text-books and other publications, and most readers are quite familiar with the statement that a film of ordinary scale, not thicker than a sheet of writing paper, would cause the loss of a very appreciable percentage of the coal burned under a boiler,—something like 10 per cent.; scale a thirty-second of an inch thick would cause 25 per cent. loss; a sixteenth of an inch, 50 per cent., and so on. Referring to this recently in a lecture at Cornell University, Mr. Walter M. McFarland, formerly an engineer officer in the United States Navy, said that to any engineer who went to sea in the old days when the working conditions caused an immense formation of scale on the heating surfaces, the utter lack of truth in this statement ought to have been manifest, his own experience having shown that a considerable thickness of clean uniform scale made apparently little difference. On the United States ship *Vandalia*, for example, there were two boilers which were used only for distilling, under normal conditions, and after a little experience these boilers were run alternately until scale had been accumulating for about three months, and yet it was found that the amount of water distilled for a given amount of coal burned was practically the same at the end of three months when the scale was nearly a quarter of an inch thick as when the heating surfaces were clean. It is, of course, true that under these circumstances the boilers were being worked at only a fraction of their full power. On one occasion, however, when there was a little discussion about this point, some one suggested a very simple test, and when one end of a piece of scale about eight or ten inches long from one of the tubes was held in the flame of a lamp it was found that the other end heated up with astonishing

rapidity, thus showing that the statements which had been made about the non-conductivity had been greatly exaggerated.

As to the formation of boiler scale, Mr. McFarland, on the same occasion, remarked that the old rule was to begin "blowing off" as soon as the proportion of saline ingredients had become about twice the normal in sea water, and this was kept up steadily throughout the voyage. The idea as to what would have happened if there had not been this blowing off must have been something wonderful, for the amount of scale which was actually produced under this regimen was enormous. It has been shown that sulphate of lime is deposited not so much on account of increased density as by elevation of temperature, thus forming an exception to the usual rule with salts which are more readily soluble in hot than in cold water. In fact, when the steam pressure was above sixty pounds every bit of sulphate of lime in the water would be deposited, even before any of the water was evaporated. The method followed, therefore, increased the deposit of scale, because it involved the introduction of an increased amount of sea water.

One immediately striking feature of the steam engine exhibit at the Paris Exhibition is the disappearance, in Europe at least, of what, in general terms, is known as the "mill engine." According to the London *Engineer*, there is not a main driving belt or a driving rope at work in the Exhibition. The few small straps through which gas engines and little steam engines of a few horse-power transmit their insignificant energy do not count. All the large engines, without exception, are employed in driving dynamos, for the most part of the fly-wheel type; and these supply power where it is wanted through cables led in various directions. The fact that there is no exception to this rule is admirable evidence of the favour with which electrical transmission is regarded on the Continent. If we are to believe what the Paris Exhibition has to tell us, electrical transmission is superseding all other methods of transferring power from place to place.

What is probably the latest form of application of compressed air is in use in the shops of one of the large machine tool firms where the air is laid on at every machine tool and serves for clearing away chips from the work, thus replacing brushes and bunches of waste. Like the compressed air car seat and carpet cleaner, which has been adopted so generally in the United States, the compressed air painting machine, the air hoist, and various other devices of the same class, this machine tool air blast promises to aid in demonstrating in a very successful way that the days of compressed air are lengthening rather than declining, and that this agent is capable of some things which are denied its possibly more brilliant rival, electricity.

The present interest in matters Chinese lends special point to an article recently contributed by Dr. John A. Church to *The Engineering and Mining Journal*, dealing with the value of Chinese mining concessions. Dr. Church has been through the Chinese "mill" and knows whereof he speaks. "In all operations in China," he says, "there is one source of expense which is not susceptible of calculation. That is the dishonesty of all hands, officials and workmen. The Chinese workman steals both for gain and because of a magpie disposition to take anything valued by another, whether it is worthless or not to himself. I have been annoyed for days by the loss of memoranda on loose bits of paper, which, being guarded carefully by the workman for whose instruction they were made, were stolen by a fellow-workman merely because they were something treasured.

It was my practice when mining in China to have the men's kits examined by a file of soldiers occasionally, and it was never done without making the most surprising discoveries. Bits of paper, a handful of nails, odds and ends of all kinds, were accumulated by men who laid themselves liable to 300 blows with a bamboo, or even loss of their heads in consequence. One part of the mine which I directed in Mongolia was in shales, and there we would occasionally find a sheet of native silver 50 or 100 ounces in weight. I doubt if the mine owners ever secured more than one of them. They had the remarkable habit of being discovered only at night, when they would be removed bodily and divided among those in the secret. Our information would come only when some lumps of the metal were found in the kit of a miner too stupid to bank it promptly. One of these little bonanzas peeped out when the American foreman was present, and we got it. Our ore was stolen constantly, and the blaze of furnaces in which it was smelted would occasionally light up the distant sky."

"OUTSIDE of our main gate was a row of forges at which the cheery blacksmiths worked openly all day making articles for the market, and every pound of the metal was stolen from my warehouses. The nails I took to that mine would build a village, and the supplies of all kinds stolen in the most open manner were immense in quantity. I had a Chinese of high rank and a magistrate who were charged especially with the duty of preventing all this. The high official lived near the gate, where all these forges were, and I have known materials to be brought in and paid for and immediately taken down to the official's house, passed through it to the outside world, brought in through the main gate again and resold to me. In one case 3000 feet of lumber were resold so often in this way that they appeared as 20,000 feet on our books. I had 800 men, and, with very few exceptions, they were as bold a body of freebooters as ever plundered the helpless. My experience was by no means unique. The beginning of Chinese railways was made while I was in that country, and the engineer in charge proposed to have the best system possible, but he was forced to give up the block system of running trains because the natives stole all the parts that lay above ground. They also stole nuts, bolts and fish-plates. It was difficult to make the American works that supplied my machinery appreciate the absolute thoroughness with which every removable part must be boxed, and the night after my goods were landed at Tientsin the manhole covers for the boilers were stolen by a casual passer by."

A CURIOUS episode in the history of strikes was recently closed by the return of 800 employees to the carpet mills at Lowell, Mass., U. S. A., after a strike of three weeks, caused by the persistency of one woman in turning out more work than her fellow workwomen. Mrs. Jessie Derrick was one of 300 women employed in the carpet mill. These women, including Mrs. Derrick, were members of a union. Last September the union made a request for an increase of wages. The management granted the request in an unlooked-for way. It fitted the looms with higher gears, thereby giving them an increased capacity. This enabled the workers to earn more in the same time at the old wages. But the union was not content with more earnings at the old wages. It wanted higher wages without increasing the output, and a rule was, therefore, adopted that not more than one piece should be produced in two and a half days, and a committee was appointed to watch the girls and see just how much work each one did. Early in April the committee reported that Mrs. Derrick was a flagrant offender against the union law in more ways than one. She had turned out more than the allotted work in the time. She had refused to remain idle when her stent was finished. She had actually gone early to the mill and

cleaned and greased her loom so as to be ready to begin weaving at the sound of the whistle. Thus she had not only violated the union rule, but had been reprehensibly industrious and thus discredited her less ambitious associates. The president of the union remonstrated with her and pointed out the wrongfulness of such industrious habits. Mrs. Derrick persisted in her right to work instead of loafing, and to earn all she could in the hours of work. A committee of the union went to the manager and demanded her discharge. The manager refused. Then Mrs. Derrick was expelled from the union, the 300 weaving girls struck, the mills were necessarily closed, and 800 employees were reduced to idleness. Pressure was brought to bear on Mrs. Derrick to submit and re enter the union, but she refused to subject her industry to the restrictions of the lazy, and the mill management stood by her. Eventually the untenableness of the position taken by the strikers became apparent to themselves. The union rule which had forbidden the doing of more than a certain amount of work within a specified time was repealed, and eventually the 300 girls marched back to their looms; Mrs. Jessie Derrick was among them, and the 800 employees of the Lowell carpet mills were again earning wages. It had been a protracted and bitter fight of one woman against 300 women, and the one woman fighting for the right of free industry won.

Sometimes a boiler explosion occurs under such circumstances that the most ardent disciple of the popular low-water theory finds it difficult to make his hobby apply. Such a case was furnished a few months ago by a boiler explosion at the quarry of a cement company, in which the primary cause of the accident was the caving-in of the quarry by which a mass of rock, weighing about 15 tons, struck the boiler near the back head, pinning that part down. In giving particulars of the occurrence, *The Locomotive*, the organ of the Hartford Steam Boiler Inspection and Insurance Company, says that every rivet was sheared in the girth joint which united the rear sheet to the rest of the boiler. The middle sheet was also flattened to some extent, apparently by the direct impact of the falling rock upon that part of the rear sheet which adjoined it. The front part of the boiler, consisting of the front head and front and middle sheets, went into the air about 100 feet and fell in the roadway, about 200 feet from its starting point. It carried the tubes with it, and, although some of them dropped out during the flight through the air, a considerable number of them still remained attached to the shell when it fell. The boiler was 60 inches in diameter and 16 feet long, with seventy-six 3-inch tubes. The question will naturally arise, whether an insurance company would be liable or not in a case of this kind, provided it was carrying a policy of insurance on the boiler. Where the policy provides simply for the possible destruction of life and property by an accident in which the boiler is the primary cause of the trouble, it scarcely seems likely that an insurance company could be held liable. In such a case the insurance obviously is against what the boiler may do, on its own initiative, and not against what earthquakes and landslides and falling buildings may do, though the case would probably not be disposed of without some interesting discussion.

According to a report on piston valves for locomotives, recently made to the American Railway Master Mechanics' Association, such valves, for steam pressures exceeding 185 pounds, offer considerably less resistance than slide valves, thus reducing the work the entire valve-gear must perform, and reducing the internal resistance of the locomotive. For steam pressures higher than 185 pounds the question of valve lubrication is very much simplified and the difficulties of cut valves and seats are very much diminished. The cost of maintaining the piston valve seems to be no greater than that of maintain-

ing the slide valve. This statement is not based on a large number of figures, but rather on the judgment of those using the piston valve. The area of admission and exit openings can be very materially increased with the piston valves, which, with higher power locomotives, seems to be a very important advantage, and it is well known that, in order to obtain the highest efficiency from a locomotive, it is not only necessary to get the steam into the cylinder promptly, but to get it out again. These are, in short, the advantages of the piston valve that seem to have been demonstrated. The committee believes that, in adapting the piston valve to the simple engine, the internal admission type has possibly a slight advantage in that the loss of heat of steam going into the cylinders is somewhat less than in the case of the external admission type.

One point in piston-valve construction, that has been found to have a material effect on steam distribution, has been somewhat overlooked, namely, the difference in area between the forward and rear end, the area of the rear end being reduced by the area of the piston rod; the two ends are, therefore, out of balance, and as a result the motion of the valve in one direction is deranged, as compared with the motion in the other direction, inasmuch as the lost motion in the valve-gear is taken up in an opposite direction from that which is ordinarily the case. This is based upon experiment on the part of the committee and from the statement of an individual to the effect that a locomotive equipped with piston valves ran for quite a distance with one of the valve-stems broken, the valve making its regular movement by being pushed ahead by the end of the broken valve-stem in one direction, and pushed back again in the opposite direction by the excess pressure on the forward end of the valve.

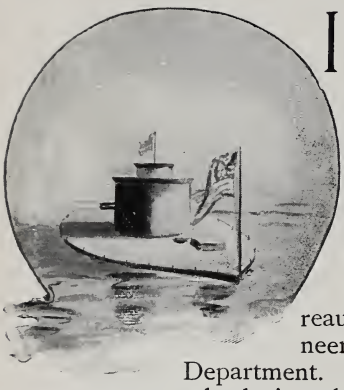
One use for aluminium which would appear to promise very satisfactory results, but of which comparatively little has yet been heard, consists in its adoption for foundry patterns, especially in foundries where the articles made are often of the same design. A wooden pattern soon suffers at its edges and corners when it is used frequently, so that it must either be repaired or renewed. If, however, the original is kept simply as a standard, the wear is practically negligible, and from it one or more aluminium patterns can be cast which can be used over and over again. Moreover, when the working aluminium pattern becomes injured, or the object which it represents is no longer in request, it can be melted down without much trouble or loss of material, and cast into any fresh shape. It is also found that aluminium patterns gradually acquire a sort of greasy surface, and separate from the sand with peculiar ease.

BENJAMIN F. ISHERWOOD

Engineer-in-Chief of the United States Navy, 1861—1869

A BIOGRAPHICAL SKETCH

By R. H. Thurston



IF there be any one individual upon whom, more than any other, the efficiency of the navy is, in time of either peace or war, dependent, that person is the chief of the Bureau of Steam Engineering of the Navy Department. This fact came out strongly during the recent war between the United States and Spain, and the labours of Admiral Melville, the talented and famous officer who has held that position during these lately past administrations, and still remains at the head of the bureau, have been very fully recognised, both as regards importance and efficiency.

But this relative importance of the bureau has not always been perceived and, in earlier days, if ever asserted, was promptly challenged. Yet it was no less true of the American Civil War of 1861 than of the Spanish-American War that it was a war conducted by a steam-navy, and that the efficiency of the then chief of the Bureau of Steam Engineering was no less important a factor in the prosecution of that war to a successful termination than the war of 1898. But, if possible, even more than now, that period was one of mighty evolutions and of important advances in steam engineering, and was hardly less remarkable for its contemporaneous work in scientific research than for its magnificent development of a fleet and a navy out of a choas of wreck of the old and comparatively insignificant and unorganised wooden, and mainly sailing, fleet.

This meant the aggregation of all available material in ships and men, the production, in great haste and with little warning, of new vessels, iron and ironclad, as well as wooden, and of new machinery from a great variety of new and often novel designs, and the conduct, by every department and every bureau, of an enormous business in the building and fitting-out, and in the details of organisation and administration, of an improvised fleet of immense dimensions. In this tremendous and enormously taxing work no man was loaded with greater personal responsibility, none was called upon for more work in longer hours or more intense application, and none was compelled to expend more thought upon original work and research involved in planning new machinery for peculiar and trying conditions, compelling investigation of scientific questions, and in professional fields of research, than was the then chief of the Bureau of Steam Engineering, Benjamin F. Isherwood.

Commodore Isherwood, in this capacity and under the singularly trying conditions of the time, made a record in quantity of work, in the efficiency of operation of his bureau, in the reliability and the permanence of his constructions, and, no less, in the extent and value of his investigations in applied science, such as probably no other man, living or dead, could rival. During four years of war he worked sixteen to twenty hours out of the twenty-four, conducted

the administration of a great bureau, gave personal attention to all its details, saw great fleets constructed, supplied designs for the machinery of the majority of its new ships, supervised their fitting-out and their maintenance and repair, and conducted numerous original scientific investigations in the endeavour to solve problems previously unsolved by exact methods of scientific research, and, meantime, published extensively and in remarkably complete and well-constructed papers and books,—the latter of exceptional excellence,—the fruits of all this extraordinary work. It is, of course, true that he had at his command all the enormous resources of his bureau and of the Navy Department, and could secure the aid of the ablest men in his corps; but the organisation and conduct of such enterprises, at such a time and under such extraordinarily difficult conditions, however great the possible facilities and the extent of available resources, is evidence of the possession at once of moral, intellectual, and physical powers far beyond the average, and of a spirit and ambition such as few men, even among the famous characters of historic times, have either possessed or concentrated upon any great purpose. The whole of the work in origination and in execution was really his own, the assistance being merely mechanical. Isherwood has made a mark upon the times, such as few men could inscribe, and perhaps none other actually has equalled, in engineering and in scientific work.

The subject of this necessarily inadequate sketch was, at that time, a familiar figure in the Navy Department and about Washington, one of the most admired, and, at the same time, one of the most abused, men of the day. He was a striking figure, as the writer recollects him, and one of the finest-looking men at the national capital. Of medium height, well-formed, quick in motion and alert in manner, he would attract attention in any group of even remarkable men. On closer approach, his strong, dark features, bright black eyes, and expressive and sensitive countenance never failed to command the attention of the stranger, and gave evidence, afterwards always fully confirmed, of a notable character within a no less remarkable frame. His curling black hair set off to great advantage rarely excellent features, and while men were interested in his always entertaining and instructive conversation,—he was a great conversationalist,—the ladies and the photographers agreed in a more æsthetic view of the man.

He was "the handsomest man in Washington" in those days, and age has not deprived him of his personal attractions of mind, and form, and feature. Delivering a lecture, a few years ago, before the Sibley College of Cornell University, upon an important phase of his scientific work during the days of the American Civil War, the audience found him as interesting, as instructive, and as entertaining as any lecturer of the course; while all admired his rapid and accurate speech and his fine rhetoric. His admirably perfect enunciation of principles and of method afforded the most inexpert full opportunity to absorb and enabled them to comprehend the most abstruse portions of his discourse. The vigour of his constitution has been illustrated in his retention of his powers into advanced life as well as by his attainments in his prime. M. V. Dwelshauvers - Dery, the distinguished Belgian engineer and man of science, now perhaps the leading continental authority in his department, refers to Commodore Isherwood as "*l'éminent ingénieur en chef de la marine des État Unis, le plus fécond des expérimenteurs de ces quarante dernières années.*"

In the two centuries now passed since the introduction of the steam-engine of Newcomen, the modern type of the steam engine as a train of mechanism, and in the century which has elapsed since its perfection in detail by James Watt, a half-dozen men have promoted the advancement of civilisation and made themselves a name by scientific investigations of the extent and nature of the defects of that wonderful thermodynamic machine, and by thus pointing to, even if not leading, the way in its further im-

provement in the direction of increased efficiency.

Of these, the first was John Smeaton (1724-72), the great English engineer who first applied scientific methods to this class of investigations, and who first, so far as we to-day know, instituted formal and exact steam-engine and boiler trials. The outcome of his work was the discovery of the fact of great wastes of heat and steam within the engine and of the defect of the machine in conductivity and by heat-exchanges between steam and internal cylinder wall. He sought to remedy the defect by, at least in part, making those surfaces non-conducting, facing his pistons and cylinder-heads with a non-conductor.

The second was James Watt (1736-1819), who sought, by similar means, to detect and to directly measure these internal wastes and to check them by his separate condensation, his steam-jacket, and his alteration of the engine from single to double-acting. He later predicted the advantage to be anticipated by the use of superheating. Watt did more than any man in the whole history of the steam-engine to improve its form and give it greater economy and efficiency.

The next man to take up these researches was Daniel Kinnear Clark (1822-1896), who investigated, principally in the locomotive, the internal losses of heat in the steam-engine cylinder, and determined roughly their law of variation with varying conditions of operation. He discovered a limit, in actual operation, to the advantage to be gained by the adoption of Watt's expedient, the expansion of steam in the engine, which is set by increasing wastes, gradually becoming equal to the increasing gains by expansion, and the overbalancing of gain by waste when that limit is reached. His work was well done, its results were unquestionable, and the principle deduced was inevadable. Its operation had been noted by the engine men at some still earlier date; Clark placed the facts on record.

Hirn (1815-1890), the famous physicist and engineer, was next in order in this series, and his work did for the stationary steam-engine what Clark had done for the locomotive, and what Isherwood did for the marine engine. He detected the fact of "cylinder-condensation," measured its amount in mill-engines, and observed its law. He published the outcome of his work and that of his younger and more highly trained aids in very accurate and scientifically acceptable form. Hirn, and Hallauer, and Dwelshauvers-Dery, conducting these investigations (1841-1888), accumulated a large amount and variety of valuable data, which formed the basis for nearly all scientific discussion of the subject on the European side of the Atlantic from their time to the present.

Commodore Isherwood was the representative investigator in this field on the American side of the ocean, and his researches relative to the efficiencies of the marine and stationary engines and of the steam-boiler, his investigations of the values, relative and absolute, of the fuels of the United States, and his study and classification and final logical and systematic reduction of results constitute for him even a greater claim to fame and permanent recognition than his enormous, and essentially professional, work in connection with the fitting-out and maintaining of steam fleets during the American Civil War. Isherwood showed himself a man of achievement, and his record, personal, professional, scientific, and literary, is an extraordinary one. In no field, however, does his intellect shine out more brightly than in his development, in those early days, and his application, of scientific methods in engineering research. In comparison with now familiar and standard methods and apparatus, those employed by him forty years ago have been in some cases thought crude, imperfect, and inaccurate; but, for their time, they were pioneer and comparatively excellent methods, and his apparatus was the very best that the art of the time could provide. Neither time, care, nor money could do more than he actually accomplished at the time. The fact is the more remarkable since the investigator

himself was educated before the time when scientific research came to form a part of the work of the graduate of the schools, and even his younger assistants were but little better trained in the practical employment of modern methods and apparatus of research.

Systematic experimental research in engineering, after being initiated by Smeaton and his contemporaries, reintroduced as the art of the practitioner by Watt, employed by Clark and Hirn, and occasionally illustrated by other engineers, was finally made a settled principle of promotion of professional knowledge and of solution of problems in practice by Commodore Isherwood for the United States Naval Engineer Corps. Thenceforward it was no longer the occasional resort of the rare man combining the scientific and the "practical" in his make-up; it was made the recognised, the permanent, and the essential element of a real advance. From that time to the present this great pioneer has seen the harvests gathered from the seed thus sown, and, curiously enough, for the next generation, the principal advances in his department of professional work, at sea and on shore, official and unofficial, have been usually made by his disciples and his colleagues and successors. Ex-engineer officers of the United States Navy, trained by him, or grown familiar during naval service with the system of investigation inaugurated by him, have retired to civil life and have there illustrated the admirable outcome of the joint work of science and art, hand-in-hand, experimental investigation preceding and guiding the art of design and the methods of construction and operation of the steam-engine.

With the general provision, especially by the State universities in America, of opportunities for a scientific training for the profession of engineering, that profession has come, since Isherwood's period of research, to be composed mainly, in its younger element, of men familiar with science as well as conversant with the arts underlying their profession, and competent to make application of every scientific system of exact investigation and research in the solution of the numerous and important problems arising in their work. Hereafter, the practice of basing all engineering work upon applied, exact science will continue to be the fundamental method of the engineer.

The lineage, birth, and early training of this remarkable man well fitted him for his later career. He inherited a positive character, a fine mind, and a strong proclivity towards scientific work and mathematical studies, as well as in the direction of mechanical engineering. Benjamin Franklin Isherwood—singularly appropriate and fortunate cognomen—was born in the city of New York on October 6, 1822. His father, Dr. Isherwood, was an alumnus of Columbia College and a pupil of a famous physician, Dr. Mott, and was himself a well-known physician of the early portion of the century. The subject of this sketch was a great-grandson of a distinguished French military engineer, Captain DuClos, an officer on the staff of General Lafayette during the American Revolutionary War, who married a Miss Stevens, of the New Jersey family of that name, and settled for the remainder of his life in the United States. This namesake of our great philosopher of those revolutionary times exhibited the salient traits of his later manhood in early childhood. He was remarkably intelligent, had a fine memory, was intellectually active and strong, and was very successful as a scholar. His education was completed at the Albany Academy, during the principalship of Dr. T. Romeyn Beck and under Dr. Bullion in classics and Professor Joseph Henry in "Natural Philosophy," as it was then customary to designate the physical sciences. Dr. Ten Eyck taught him mathematics, and the principal gave him instruction in *belles-lettres*. The school was, in its time, very famous and successful.

On completing his school education, he was taken under the wing of David Matthews, a well-known master-mechanic of the time, on the mechanical engineering work of the Utica & Schenectady Railroad, after a short inter-

mediate period of employment under William C. Young, the civil engineer of the road. There he acquired that familiarity with the details and methods of design and construction which stood him in such good stead in his later naval work. William Lake, a very distinguished British civil engineer, was his preceptor and immediate superior in that earliest period of his work in the civil engineering department, being at the time the resident engineer. On the completion of the road the force was necessarily reduced, and Isherwood was sent, with strong letters of recommendation, to the chief engineer of the Croton Aqueduct, then under construction under the direction of John B. Jervis, another engineer who attained great distinction in later years as the inventor of the truck or "bogie," the general use of which constitutes a characteristic of American locomotive construction, as distinguished from the European system of rigid wheel-base, as a writer of authority on industrial subjects, and as a man of peculiar genius in construction.

On the completion of the aqueduct a new position was promptly offered him, on the Erie Railroad, with Charles B. Stuart, then a division engineer at Susquehanna, and later connected with the U. S. Navy in the capacity of engineer-in-chief. This acquaintance was probably one of the essential incidents in the train of circumstances which, afterwards, brought Isherwood into the service and into that position in which he made his name so famous. His next duty was an assignment by the U. S. Treasury Department to work, under Stephen Pleasanton, in the construction of lighthouses, which work was then under the supervision of Pleasanton, the Fifth Auditor of the Treasury and Superintendent-General of Lighthouses. He was sent to France and instructed to superintend the construction of lighthouse lenses there under construction from designs by himself. This experience was particularly pleasant and instructive, and was a welcome change from the routine of the engineer.

Meantime, the engineer corps of the navy was organised and Isherwood entered among its first appointees, finding a great variety of work, sometimes in its regular and usual field of operations, sometimes in scientific matters outside its strictly legitimate range. He continued to do some work for the Lighthouse Bureau, but, the Mexican War breaking out, he promptly found occupation at sea. He served on the *Princeton*, the first American screw steam vessel, built by Ericsson for the government as an experiment, and which proved the pioneer of the United States steam navy. In this ship he took part in all introductory experimentation with steam as a motor for war vessels, and presently, as chief engineer of the *Spitfire*, saw and took part in every action in which the American fleet was engaged during the war. At Vera Cruz this ship, alone and unaided, attacked the castle of San Juan d'Ulloa. He was advanced to the *San Jacinto*, on board which ship, as chief engineer, he served throughout a three years' cruise in the Asiatic Squadron.

Whether at sea or on shore, Isherwood was continually on duty and as constantly engaged in the study and solution of the infinite number of practical and scientific problems then facing the engineer. Systematic research had, up to that time, been almost unknown and unrecognised in the world of engineering, now so absolutely relying upon applied science for its fundamental facts and principles. He inaugurated systematic experiment, planned researches and conducted investigations in a great variety of directions and fields of application, employing the best facilities and apparatus at the time available. He was employed by the Navy Department on its boards of survey, of investigation, and of examination, and steadily became more and more recognised as an authority and a reliable reporter on the applications of science bearing on the work of his corps.

In 1859 were published two volumes of "Engineering Precedents," in which the results of investigations of the distributions of energy and work throughout the motive-power system of a steam vessel were exhibited. It was the first

attempt of the kind of any importance, and was based upon an extensive series of investigations of the indicated power of the engines, of their losses by their own friction and friction wastes in the transmission of the developed power of the engines to and through the propelling apparatus, and of the net amount expended in the actual propulsion of the ship itself.

Four years later, in 1863, was published the first volume of "Experimental Researches in Steam Engineering," followed, in 1865, by the second volume, in which were detailed the investigations made respecting the economy of Watt's principle, the expansion of steam in the engine, as actually adopted in the engines of the United States Navy at that time. The "*Michigan* Experiments" were, in fact, largely the foundation of Isherwood's fame as an investigator and student in applied science. The work was undertaken under orders of the United States Navy Department in 1860, and its results created the most extraordinary excitement and the most remarkable disputation not only among engineers, but, curiously enough, as it appears to the onlooker, with the seamen of the navy.

Throughout the engineering world the announcement, then made for the first time in a manner to attract general attention, that the Watt system of expansion of steam was practically unavailable beyond a very small value of the ratio of expansion in the engines studied, awakened unusual interest, and the statement was challenged in all directions, sometimes as a matter of fact, sometimes as a matter of scientific principle. By many the results were challenged as practically inaccurate and incredible; by others it was asserted that they were contrary to natural law and absurd on their face. As the investigator went on with his work, in other cases and under other conditions, however, the extreme care, and, for the time, exceptional and minute accuracy of his results, became recognised and admitted, and, though pioneer work, they stand to-day as valuable contributions to human knowledge and professional information in this field.

Isherwood's studies of the influence of the wastes of the steam-engine upon its efficiency and in modification of our deductions from the thermodynamics of the theory of the ideal machine, in application to the real engine, promptly exhibited not only the fact of a practical limit to the use of expansion, but revealed as clearly the reason of its existence. Immediately upon the proof being secured of a steady increase in the proportion of steam condensed, without doing work, with increasing expansion, it became obvious that, with increasing wastes and progressively decreasing gains by expansion, there must be ultimately found a point beyond which further economical expansion becomes impracticable. Isherwood showed the fact and also the position of this limit in the engines of the navy of his time. That this limit should be found at so early a point in the stroke of the piston was a matter of more than surprise, of real astonishment, to all the world, not only of science, but of engineering as well.

The fact was repeatedly challenged, but direct experiment over and over again corroborated Isherwood's deductions, and the extraordinary storm of contradiction, challenge, and even personal and professional abuse which arose on the publication of these unlooked-for truths was calmed only by an actual competition between two war vessels, of duplicate hulls and with steam machinery constructed in precise accordance with the deductions of Isherwood and from the plans of the recognised exponent of a radical practice, respectively.

The work on the *Michigan* was repeated on other naval vessels of various types and under differing conditions of operation, and the general fact became distinctly clear. It was soon made certain that in every steam-engine cylinder there is a certain degree of expansion which constitutes a limit beyond which further expansion of the working charge produces a net loss rather than gain, and it was further shown that, in all the engines of the time, this limit was far

within that set by the termination of the expansion line of the indicator diagram at its intersection with the back-pressure line. In the *Michigan* class, for example, it was found that, under the conditions of the reported trial, while the ratio of expansion would be, for the thermodynamic case, for the ideal, about forty, the actual ratio of best duty effect was only about two, and, with engines of the same class, operated under more favourable conditions, and representing a fair average for the time, not above two and a half.

The *Algonquin*, built with a high-pressure engine and boiler, and constructed to operate with a correspondingly high ratio of expansion, was set against the *Winooski*, constructed for the then usual low steam pressures of the service and the low ratio of expansion found most economical in the experiments of Isherwood, and the result, greatly in favour of the conservative practice, settled the dispute promptly and effectively. The fact thus shown that, to avail ourselves of high-pressure steam and of the advantages of expansion, the wastes of the engine must be suppressed, thus became proved and fully recognised.

The deductions were finally admitted by the profession to be unquestionable as to character, and as accurate as the then available means and methods of investigation would permit. This publication attracted the attention of engineers strongly to an important, but previously greatly neglected, subject and led to many later and extensive studies of the same problem; but none of late date have been more complete and satisfactory, the circumstances and the time considered, than those of Chief Engineer Isherwood.

The publication of these facts, in the complete and convincing form in which the investigator presented them, rendered certain and indisputable those deductions which have since become settled and have become the basis of a true and complete theory of the real steam-engine. They were, with the work of Hirn and of Clark, and of Watt and Smeaton, the fundamental basis of what Hirn had denominated the "experimental theory of the steam-engine." The originality of the work and the importance and influence of the discovery made were well evidenced by the world-wide and universal doubts and denials awakened.

It was but four years earlier that Rankine had published his "Manual of the Steam-Engine and Other Prime Movers," in which he collated into systematic form those principles of thermodynamics which he and, almost simultaneously, Clausius, had enunciated, ten years earlier, and upon which these great men had constructed the whole of the essential modern theory of thermodynamics, building up that science, each in his own way, into final and acceptable form. Clausius, however, had little knowledge of applied thermodynamics as illustrated in the heat-engines, and made no attempt to evolve an applied science. Rankine, on the other hand, an engineer by profession, sought, as his main object, the production of an applied theory, and his "Manual" is professedly, but mistakenly, a treatise on the applied science of the steam-engine. It is, actually, a discussion of the pure science of the case, and its conclusions and deductions are only those relating, correctly, to the "ideal case." Isherwood's investigations proved clearly that the thermodynamic theory must be supplemented by the physical theory of the thermal and the dynamic wastes to make the applied science of the heat-engine complete and practically applicable to the purposes of the engineer. A share in this important progress is one of the foundation stones of the fame of the author of "Researches in Steam Engineering."

The outbreak of the American Civil War did not interrupt Isherwood's scientific and research work. He was appointed by President Lincoln and his Secretary of the Navy, Gideon Welles, as the chief of the Bureau of Steam Engineering, then just organised, and entrusted with the work of building up a steam navy that should successfully cope with the tremendous task of destroying the organised rebellion which so sud-

denly took form in 1861. This task was magnificently accomplished, and a fleet of six hundred ships, including war vessels and blockading craft, was produced. The personnel was secured and organised, and the administration of the work of construction and of operation was promptly and marvellously well effected. The designing of the new ships of the regular navy was mainly accomplished by the Navy Department bureau. Engineer-in-Chief Isherwood saw all machinery designed, and supervised its construction in private and public shipbuilding and machine building establishments throughout the whole American coast-line. Some of these ships were of novel classes, and the performance of the larger and faster vessels established new "world's records." Mr. Isherwood continued in this position until after the close of the war, serving eight years under Lincoln and Johnson.

During this whole period his experimental work continued, and the opportunities which such enormously extensive operations offered for the prosecution of his researches were fully utilised. The performance of every class of steam-boiler, with every form of fuel, that of many types of steam-engine and of numerous classes of wooden and ironclad ships, and, in fact, every problem presenting itself to the designing and constructing and operating engineer, became the subject of his never-ending, indefatigable, and always useful work of investigation. His eight-year term of service was closed with a most extraordinary record of productivity and of skill in creation and administration, in face of most bitter persecutions and of strenuous, and unreasonable, and unreasoning personal and political opposition.

The remainder of the period of his active service was given to extensive foreign tours, studying foreign navies and constructions and naval stations, and to the prosecution of additional experimental work, as presiding officer of various naval experimental commissions, under the authority of the later Secretaries of the Navy. When retired, with the rank of Commodore, in 1884, at the age of sixty-two, his strength was still unimpaired, his mind was as active as ever, and his interest in the world about him was as keen and strong as during his period of greatest activity.

He still resides in New York, in a modest home which has been his for many years, and he is still busy with study, investigations, including valuable translations from the French, and literary and scientific work. His work has, meantime, become well-known and recognised at its true value by all members of his profession, and the conclusions once ridiculed and denied by many, even among the so-called "authorities" of their time, now are the basis of much of the modern engineer's advanced practice. His researches, made at an early date and with comparatively crude and unsatisfactory apparatus, such as only could then be provided, and before many of the most important of the engineers' instruments of investigation had been invented, are still found to be substantially corroborated by the most extensive and accurate of recent scientific investigations in that field. His work is done, and is found to have been well done, and his reputation and his standing among the pioneers in the application of scientific methods to engineering are firmly established for all time.

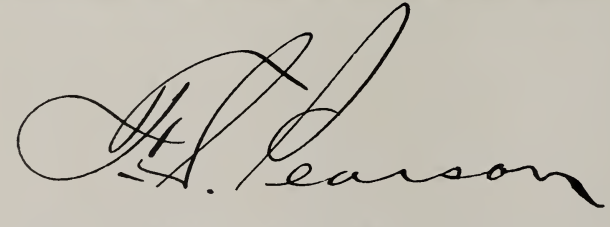
His record, as in but fractional part preserved in the published works which have been mentioned, includes studies of the economy of steam-engines, of the sources of their defects of efficiency, of the conductivities of the materials employed by the engineer in his boilers, engines, condensers and other constructions, of the relative values of the substances employed as non-conductors in the prevention of wastes of heat, of the merits and the advantages and disadvantages of natural and forced draught, of the heating values of all the familiar fuels, especially American coals, and, on a large scale and under the conditions of standard practice and determinations, of the performances of war vessels especially, including those which he invented,—the term may be properly here employed,—the series culminating

with his *Wampanoag* class of cruisers, making the then unexampled speed, for a craft of 4000 tons, of 16⅔ knots, hour after hour, for twenty-four hours together. Even the forms of the hulls were largely Isherwood's; for the naval constructor of the time at the Navy Department was a personal friend, as well as official coadjutor, and the two worked out that problem together.

It has been the fortune of the writer to have been familiar with, and for more than eleven years a part of, the organisation of the then "new navy" of the United States, thus so largely created by this master-mind, and to have been, from 1861 onward, more or less in contact with Commodore Isherwood and his work, and thus to know well the details of this life and work which has constituted so important a part of the history of the American Navy and of the United States. He was assigned by Commodore Isherwood to his first berth on the first gunboat built by the government during the Civil War, was appointed, through his advice, engineer-in-charge of an "Isherwood gunboat," later, was given extensive opportunities for experience and observation, and of investigation, during the active period of the war, on a great variety of ships and with a hardly less remarkable variety of steam machinery, and was finally detailed by him to the U. S. Naval Academy, to a six-years' term of service under the most delightful and profitable circumstances; through the whole decade, and more, becoming more and more familiar with the man and his work, whether in designing machinery, inventing new types of vessel, conducting researches, or maintaining the standing and dignity of his corps, and he feels that he is prepared to give true testimony in behalf of the officer, of the professional, of the investigator, and of the man. All in all, it may be confidently asserted, Benjamin Franklin Isherwood has justified fully the honour paid him in every capacity. As an officer of the government, he performed the great tasks assigned to him with energy, intelligence, and efficiency; as an engineer, he accomplished great professional work in a wise manner; as an investigator, he performed his task with genius, skill, and accuracy, and a judicial mind; as a man, he never failed a friend, or feared an enemy, or evaded a duty, and he has lived a life fruitful in all good works.

A generation ago the virtues of the man made him the "best-abused" member of the engineering profession. His scientific work was doubted and depreciated; his official position exposed him to jealousy and political and class obloquy; his professional standing was questioned. To-day his professional and scientific work have been properly rated; his corps has been admitted to its rightfully high place in the service of the nation and among professionals; and his youngest have joined with his oldest colleagues to unite in a memorial to Congress asking the acceptance of a bronze bust of their hero for a permanent memorial, to be installed in the Library of Congress or other suitable public place of honour. Rarely can be found a more deserving subject of such a tribute from friends, from the profession, or from the nation. "*Vincit omnia veritas!*" May the victor live long to enjoy his victory!

PHOTO BY ALMAN & CO., NEW YORK



CONSULTING ENGINEER OF THE METROPOLITAN STREET RAILWAY COMPANY, NEW YORK

SEE PAGE 446

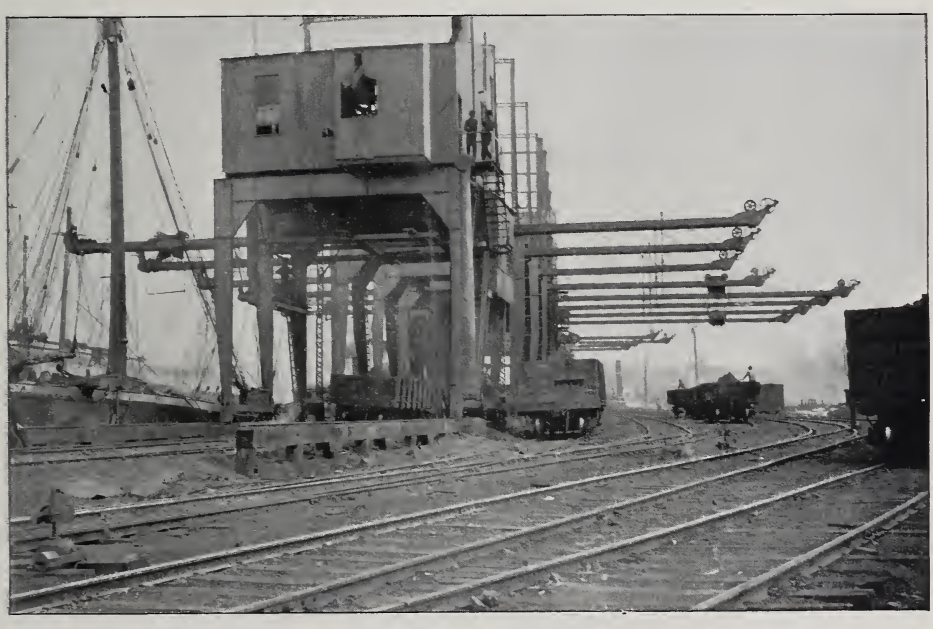
CASSIER'S MAGAZINE

VOL. XVIII SEPTEMBER, 1900 No. 5

AMERICAN ORE DOCK MACHINERY

FOR HANDLING BULK CARGOES OF COAL AND ORE ON THE GREAT LAKES

By Arthur C. Johnston



UNLOADING ORE DIRECT FROM VESSELS TO CARS, WITH MACHINERY BUILT BY THE BROWN HOISTING AND CONVEYING MACHINE CO., CLEVELAND, OHIO

THE statement has been made that it is possible to take ore from the Lake Superior iron ranges and convert it into steel plate at Pittsburgh within ten days. When we consider that the mines and the furnaces are separated, in round numbers, by one thousand miles, and that the ore undergoes two shipments by rail and one by water, in cargoes of from four to eight thousand tons, we are able to realise to what a high degree of efficiency the machinery for the transportation, the loading and unloading, and the transfer of cargoes, has been brought. It is proposed in this article to consider the special types

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A DIRECT ORE UNLOADING PLANT BUILT BY THE McMYLER MFG. CO., CLEVELAND, OHIO, FOR THE PITTSBURGH & CONNEAUT DOCK COMPANY

of dock machinery built for the purpose of insuring "quick dispatch" in loading and discharging the enormous tonnage of ore and coal that is shipped annually on the Great Lakes, the shipments of ore alone being one-third of the entire lake freight traffic.

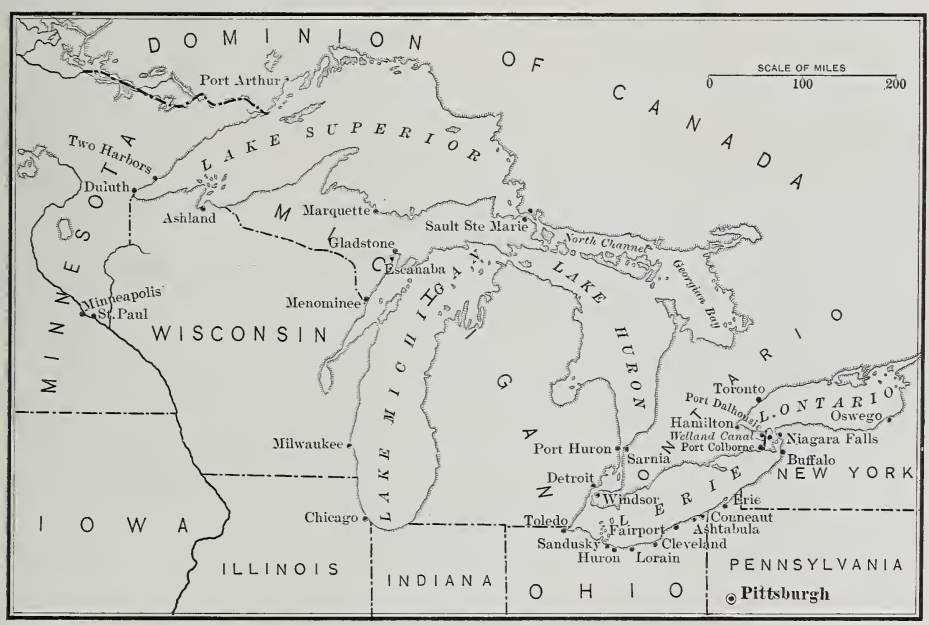
A recently issued report of the United States Bureau of Statistics says that the remarkable dispatch effected in handling these cargoes "is, in a large measure, gained by building vessels and docks adapted to one another." Lake vessels, built for the ore and coal trade, are indeed special types, the distinctive features being the shallow holds, made

ORE DOCKS IN THE LAKE SUPERIOR DISTRICT.

Railway.	Location.	Dock No.	Length of Dock in Feet.	Width of Dock in Feet.	Height of Dock Water to Deck.	No. of Pockets.	Storage Capacity. Gross Tons.
Duluth & Iron Range R R. Co.	Two Harbours, Minn.	1	1,056	41′0″	45′6″	141	18,000
		2	1,248	....	57′0″	208	41,600
		3	540	49′6″	51′6″	90	16,000
		4	1,008	49′0″	51′6″	168	30,000
		5	1,008	49′0″	54′0″	168	33,000
Duluth, Mesaba & Northern.	Duluth, Minn.	1	2,340	52′0″	53′6″	384	57,600
		2	1,738	52′0″	57′4″	288	42,400
Duluth, Superior & Western Ry.	Allouez Bay	1 a	300	49′8″	52′0″	40	12,000
	Superior, Minn.	1 b	1,200	49′8″	57′0″	150	25,500
Chicago & North-Western R. R.	Ashland, Wis.	1	1,404	46′8″	54′0″	234	36,036
		2	1,404	46′0″	58′8″	234	24,156
	Escabana, Mich.	1	1,404	37′0″	46′0″	184	24,104
		3	1,356	37′0″	39′0″	226	30,284
		4	1,500	37′0″	50′2″	250	37,500
		5	1,392	37′0″	51′10″	232	43,152
Duluth, South Shore & Atlantic R. R.	Marquette, Mich.	1	1,700	40′0″	45′0″	270	27,000
		3	1,200	53′6″	37′0″	213	12,780
		4	1,200	36′8″	47′3″	200	28,000
Lake Superior & Ishpeming.	Marquette, Mich.	1	1,200	52′0″	54′0″	200	36,000
Minneapolis, St. Paul & Sault Ste. Marie R. R.	Gladstone, Mich.	1	768	37′0″	47′0″	120	15,000
Wisconsin Central Lines.	Ashland, Wis.	1	1,908	36′0″	54′6″	314	33,500

necessary by shallow rivers and harbours, the great beam and the large size and number of hatches. The largest vessels are 500 feet long and 50 feet beam, the hatches being 30 to 34 feet long by 8 feet wide, and spaced 24 feet from centre to centre along the entire available deck length. Loading and unloading operations are thus greatly facilitated, and, in spite of the fact that the deck plating is almost cut in two at every hatch, a fairly strong hull is obtained. Cross-sections of these vessels are shown on page 360.

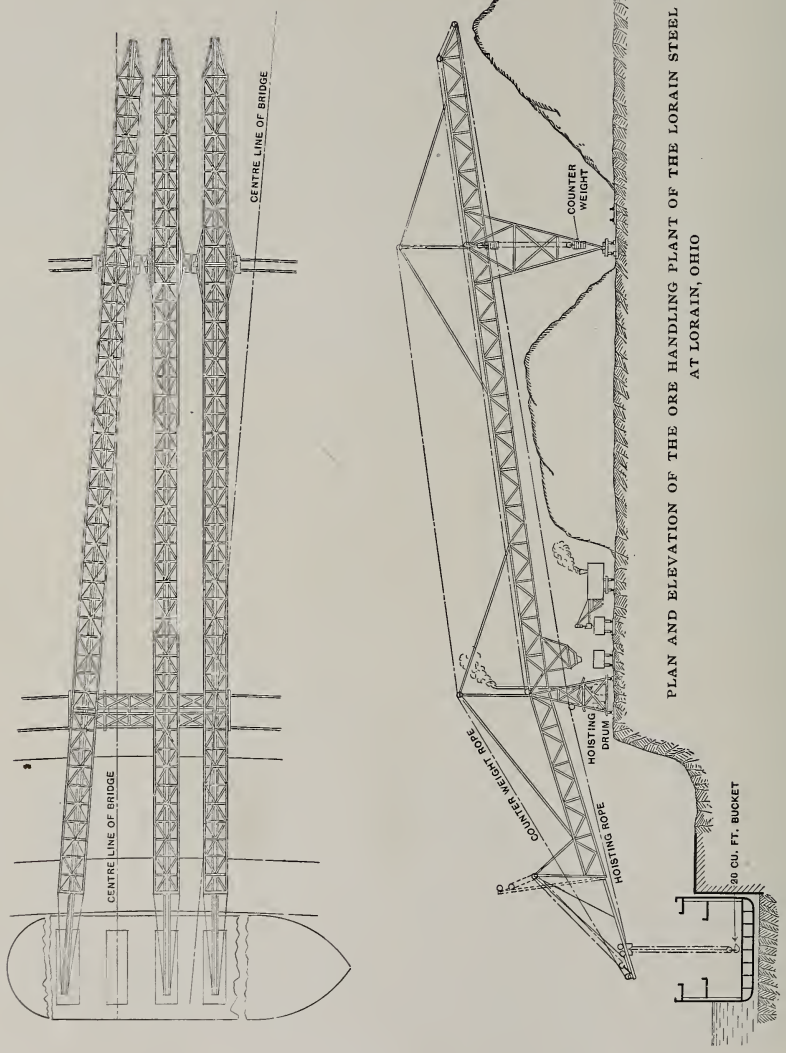
The mines of the Lake Superior district are located from twelve to sixty into the vessels lying alongside. The chutes are spaced twelve feet from centre to centre, so that every second chute is lowered into one of the hatches, which are 24 feet from centre to centre. When the contents of the pockets whose chutes are first lowered have been discharged into the hold, the vessel is moved forward 12 feet and the intermediate chutes are brought into position for loading. The chutes being adjustable, no trimming of cargo is necessary, and thus it will be readily understood how it is possible for a vessel to come alongside one of these docks, take on a cargo of from 5000 to 8000 tons of ore and depart



THE PRINCIPAL PORTS ON THE GREAT AMERICAN LAKES

miles from their respective shipping ports, and the ore is carried to the docks in specially constructed drop-bottom "Jumbo" cars of from 25 to 30 tons capacity each. The cross-section of a typical ore loading dock, and the method of loading vessels, are shown in the lower cut on page 360. As will be readily understood, the ore cars are run out on the dock and their contents are discharged into the pockets, and, through the chutes, within a few hours from the time it reached port.

Some of the ore-loading docks are almost half a mile long, and, with very few exceptions, they are all over 1000 feet long. In 1899 there was at the different ports a total of 4354 pockets, having a storage capacity of 623,612 gross tons of ore, constructed at a cost of about $7,000,000. In the table on page 356 will be found a list of docks, with location and principal dimensions,



PLAN AND ELEVATION OF THE ORE HANDLING PLANT OF THE LORAIN STEEL COMPANY, AT LORAIN, OHIO

and the names of the railway companies owning them.

The output from all the mines of the Lake Superior region, from 1895 to 1899, inclusive, is given in the table on page 361.

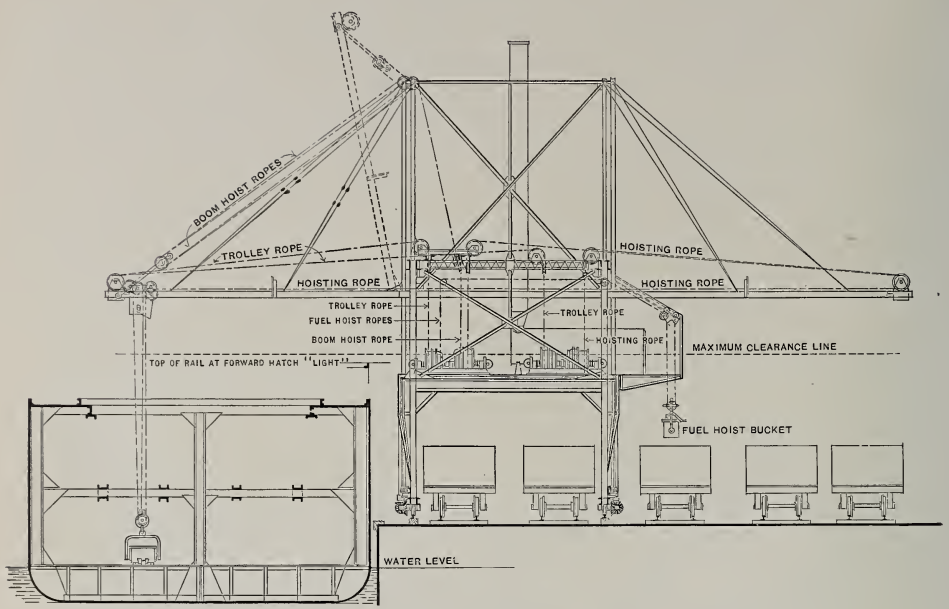
Thus it will be seen that the combined capacity of the ore docks is none too great, since in 1899 there were shipped 17,901,358 tons of ore through a dock storage capacity of only 623,612 tons.

The machinery on these docks reheel of the spout is 40 feet above the water-line.

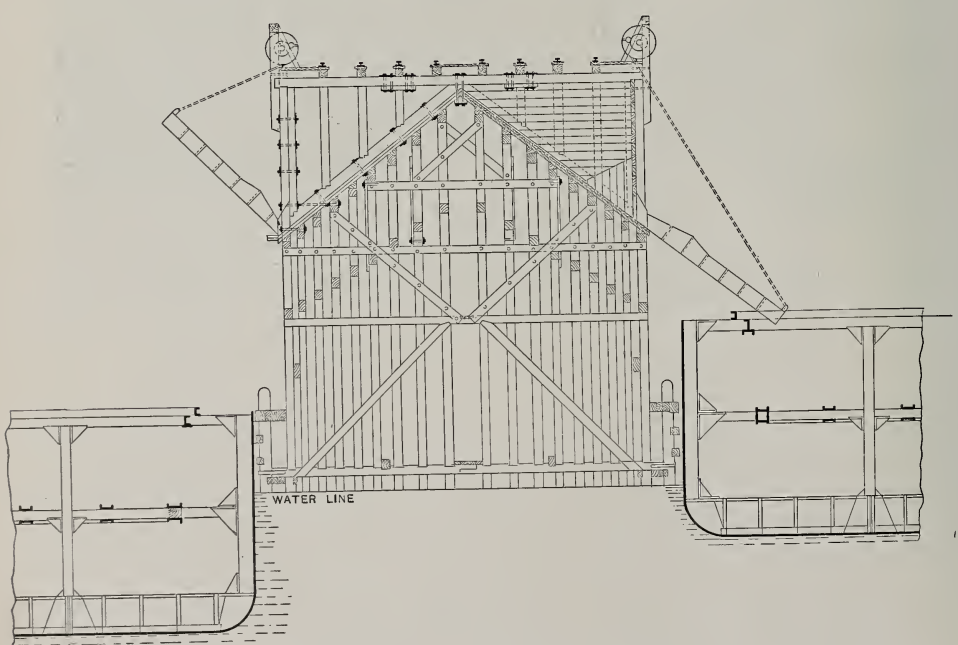
South Chicago, on Lake Michigan, and Lake Erie ports are the receiving points for the ore, and most of these ports are very well equipped for the rapid discharge of cargoes, both for dock storage and direct loading into railway cars. One of the most recent and largest installations is that shown on page 358. This plant is on the docks of the Lorain Steel Company, at Lorain,

STEAM SHOVEL BUILT BY THE THEW AUTOMATIC SHOVEL CO. LORAIN, OHIO

solves itself into the mechanism for controlling the chutes, these being generally over-counterbalanced through a differential drum so that they will fly up if let go; hand winches are worked to lower them. All the new docks are being built higher than the old ones, in order to reach the largest vessel that is ever likely to be built on the lakes. The Duluth, Mesaba & Northern Railway has just built a new dock which is 66 feet 6 inches high, 62 feet wide, and the Ohio, and the high bluff behind the dock has made necessary the introduction of some peculiar features in the design of these machines, notably the long cantilever of 127 feet overhanging the boat; and the desire for great storage capacity involved the great length of bridge and rear cantilever. These machines are built in groups of three bridges, hinged at three points on a single front tower, which, however, is "telescopic," so that the pivotal points



DIRECT ORE UNLOADER BUILT BY THE MCMYLER MFG. CO., CLEVELAND, OHIO



CROSS SECTION OF ORE POCKETS

may be racked in and out from one another by steam power in order to accommodate any spacing of hatches. The rear towers are independent, and are moved by a locomotive running on a track parallel to that on which they

ore and 2500 pounds of hard ore. The operations of hoisting and transporting the bucket are performed by a single rope. The bucket can be dumped at any point along the bridge by placing an automatic trip at the desired point. The

A TYPICAL HOPPER BOTTOM ORE CAR OF 100,000 LBS. CAPACITY. BUILT BY THE PRESSED STEEL CAR COMPANY, PITTSBURGH

themselves travel. Thus, an individual bridge may be made to assume any desired angle, within limits, in order to reach the different hatches.

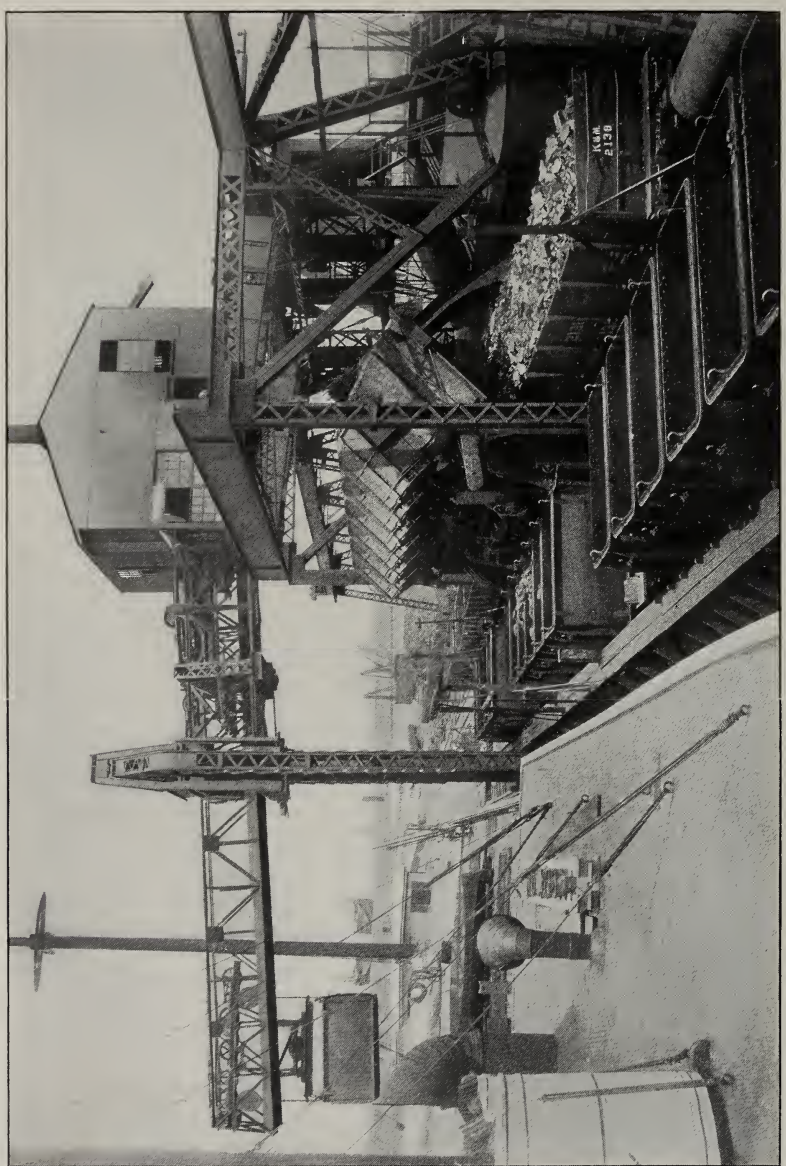
These machines handle a bucket of 20 cubic feet capacity, the details of which are shown in the diagram on page 365. It has been found by experience that the most economical size of bucket to use in connection with ore hoists is one of from 17 to 20 cubic feet capacity, as a larger bucket is so heavy that the handling of it takes the men in the hold away from the work of shoveling and entails loss of much time. Seventeen cubic feet correspond to one gross ton of light soft

furnaces are located directly behind the hoists, and, if desired, the ore can be dropped through the suspended hopper, shown between the towers, into stock cars and carried to the furnaces without first going to the stock pile.

Each bridge of these conveyors is equipped with a pair of 12 × 12-inch non-reversing engines, which carry, mounted loose on their crankshaft and driven through a friction clutch, a single drum, 40 inches in diameter. The "waggon" is arranged with a "three-part" hoist, but in traveling along the bridge the full circumferential speed of the drum is effective on the waggon, so that a single revolu-

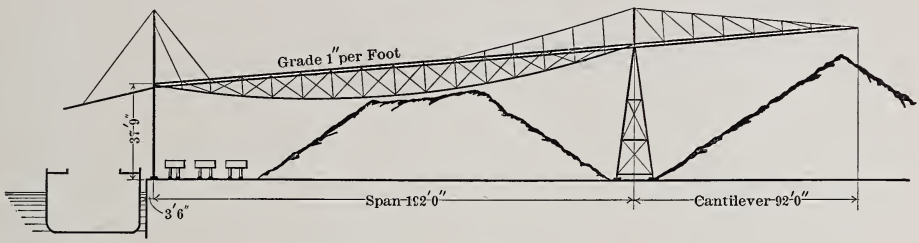
THE LAKE SUPERIOR MINE OUTPUT FROM 1895 TO 1899.

Ports.	1899 Tons.	1898 Tons.	1897 Tons.	1896 Tons.	1895 Tons.
Escabana,	3,720,218	2,803,513	2,302,121	2,321,031	2,860,172
Marquette,	2,733,596	2,245,965	1,945,519	1,564,813	1,079,485
Ashland,	2,703,447	2,391,088	2,067,637	1,566,236	2,350,210
Two Harbors,	3,073,733	2,693,246	2,651,465	1,813,092	2,118,156
Gladstone,	381,457	335,955	341,014	220,887	109,211
Superior,	878,942	550,403	531,825	167,245	117,884
Duluth,	3,502,965	2,635,262	2,376,064	1,988,932	1,598,783
Total by Lake,	17,901,358	13,655,432	12,215,645	9,644,036	10,233,910
Total by Rail,		369,241	253,993	290,792	195,127
Total Shipments,	17,901,358	14,024,673	12,469,638	9,934,828	10,429,037



CAR DUMPER BUILT BY THE BROWN HOISTING AND CONVEYING MACHINE CO., CLEVELAND, OHIO

tion of the engine lifts the bucket 3 feet 5⅝ inches in hoisting, and draws the waggon 10 feet 5 inches along the bridge in trolleying, thus making the machines very quick in action. The operator in



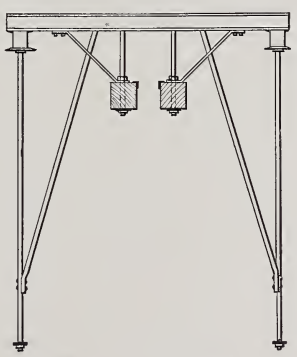
ORE HOIST AND CONVEYOR BUILT BY THE BROWN HOISTING AND CONVEYING MACHINE CO., CLEVELAND, OHIO

the top of the front tower, in full view of the hatch, controls the motions of the bucket by two levers and a foot brake. One lever controls the throttle of the engine, the other the friction clutch driving the drum, and the foot brake controls the speed of the returning waggon down the incline, and the lowering of the bucket into the hold.

The engines are equipped with auxiliary drums for hoisting the boom or "apron" that overhangs the boat, and they are also arranged to rack the "telescope" and to propel the front tower bodily along its track parallel to the dock face. These machines have made some remarkable records in point of speed, as an individual waggon has made fifty return trips per hour, carrying the bucket from the bottom of the boat to a point half way between the towers. The best cargo record was 3241 gross tons taken out in twelve and one-half hours by six bridges.

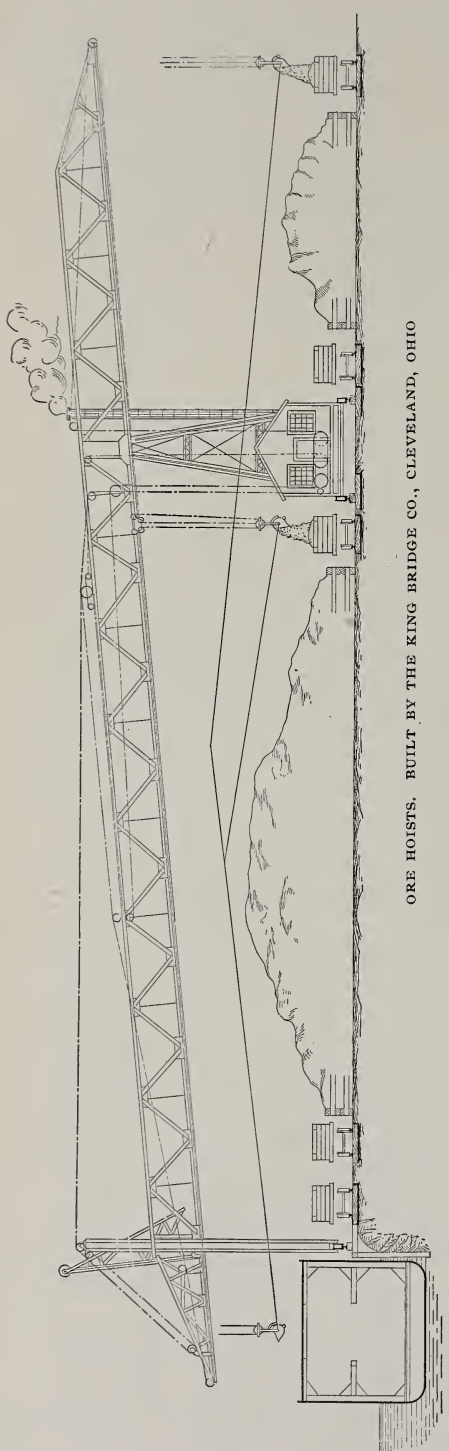
Another type of ore unloader for dock storage is shown on this page. It differs from the Lorain machines in that the rear tower carries the pivotal point of the bridges, and the front towers are independent of one another. The operator and engines are also in the rear tower, the engines having single-reduction gearing between the crankshaft and drum, thus using smaller engines with a higher piston speed. One of the great advantages of the form of bridge truss used is that it is theoretically correct, and consequently its weight is reduced to a minimum, and, at the same time, the track is carried near the top chord and the bucket is suspended between trusses, thus reducing the clearance required for it to that of the truss, which gives a greater dock storage capacity for a given height of bridge.

A machine differing radically from those shown on this page and on page 358 is that shown on page 364. Its distinctive feature is the great freedom of motion of the bucket. In the machines first mentioned the hanging block is locked in the waggon and cannot be released without striking a stop, which is bolted between the tracks. Thus, when



END VIEW OF TOWER

unloading very narrow boats, the front stop on the "apron" must be moved in till it is vertically over the centre of the hatch; and, similarly, if it were desired to load a car on a track under the rear cantilever, a stop must be placed over the centre of the track to allow the bucket to be released from the waggon and lowered to reduce the fall of the



ORE HOISTS, BUILT BY THE KING BRIDGE CO., CLEVELAND, OHIO

ore. With the machine shown on this page, however, the bucket can be raised or lowered to any desired height simultaneously with its travel along the bridge. The dock records of Conneaut harbour, at Conneaut, Ohio, show that nothing is lost in point of speed of operation, and the only disadvantage of the system is that three drums and reversing engines are required for its operation.

The ore storage docks of the lower lake ports form the base of supply upon which the furnaces of the Pittsburgh district draw their supply during the four months of closed navigation. During the season of navigation, however, when cars are available, ore for reshipment is loaded directly from the boats into cars, nearly all the ore-carrying railways being well equipped with steel cars of 100,000 pounds capacity.

The latest plant for direct unloading is that shown at the top of page 360, and as it has attracted a great deal of attention from engineers and others, a description of the equipment will be of interest. The machines are built in groups of three bridges each, so arranged as to be able to cover any spacing of hatches from 21 to 36 feet from centre to centre. Five loading tracks are covered by the bridges, which reduces the work of moving cars to a minimum, and the machines themselves can travel along the dock by steam. Each unit of three bridges is equipped with an 80 horse-power, locomotive-type boiler, which supplies steam to three pairs of $10\frac{1}{2} \times 14$-inch engines, —one pair of engines for each bridge. Each of these engines carries on its crankshaft 40-inch drums for both hoisting and trolleying. A feature of the arrangement is the method of controlling the clutch and brake for the trolleying drum, by using a steam cylinder, which, when it sets the brake, at the same time releases the clutch, and *vice versa*. The cables for hoisting and trolleying are of nine-sixteenths plough steel, and they run on 24-inch sheaves throughout, except in the waggon, where they are 17 inches, and in the hanging blocks, where they are 15 inches in diameter. The

CAR DUMPER BUILT BY THE McMYLER MFG. CO., CLEVELAND, OHIO, FOR THE PITTSBURGH & CONNEAUT DOCK CAMPANY

problem of keeping fast-running cables that are subject to sudden stops and reversals on their sheaves has always been a serious one, but it has been found that the rope guard used on these machines and shown in the diagram on page 366 has completely removed all difficulty. It consists of two cast iron mouth-pieces of such shape as to render fouling of the cable impossible. The pieces are connected by a wrought iron strap, which keeps the cable from jumping.

The capacity of this plant, which includes four machines of three bridges each, is given as 6000 gross tons in twelve hours; but it has many times exceeded this. For instance, a cargo of 6155 gross tons was unloaded into cars in nine hours, giving an average for the cargo of 683.8 tons per hour for the whole plant, or 56.9 tons per hour for each bridge.

Another modern plant for direct unloading is that on the docks of the Cleveland & Pittsburgh Railway. The extent of its equipment is well shown in the illustration on the opening page of this article. Some of the machines have independent towers for each bridge, and some are arranged with two bridges on an individual machine.

For loading ore from the dock into cars a type of shovel that is particularly adapted to this work is shown on page 359. Its distinctive feature is that the

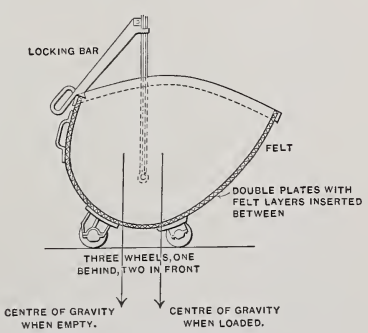
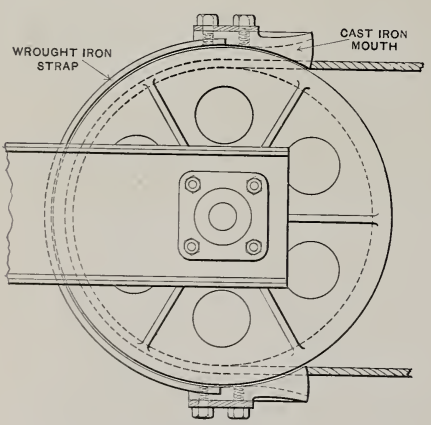

LOCKING BAR
FELT
DOUBLE PLATES WITH FELT LAYERS INSERTED BETWEEN
THREE WHEELS, ONE BEHIND, TWO IN FRONT
CENTRE OF GRAVITY WHEN EMPTY.
CENTRE OF GRAVITY WHEN LOADED.

DIAGRAM OF AN UNLOADING SKIP

THE HULETT ORE UNLOADER. BUILT BY THE WEBSTER, CAMP & LANE MACHINE CO., AKRON, OHIO

pivotal point of the scoop arm has a horizontal movement, which has the effect of moving the scoop parallel with the floor of the dock, thus being able to



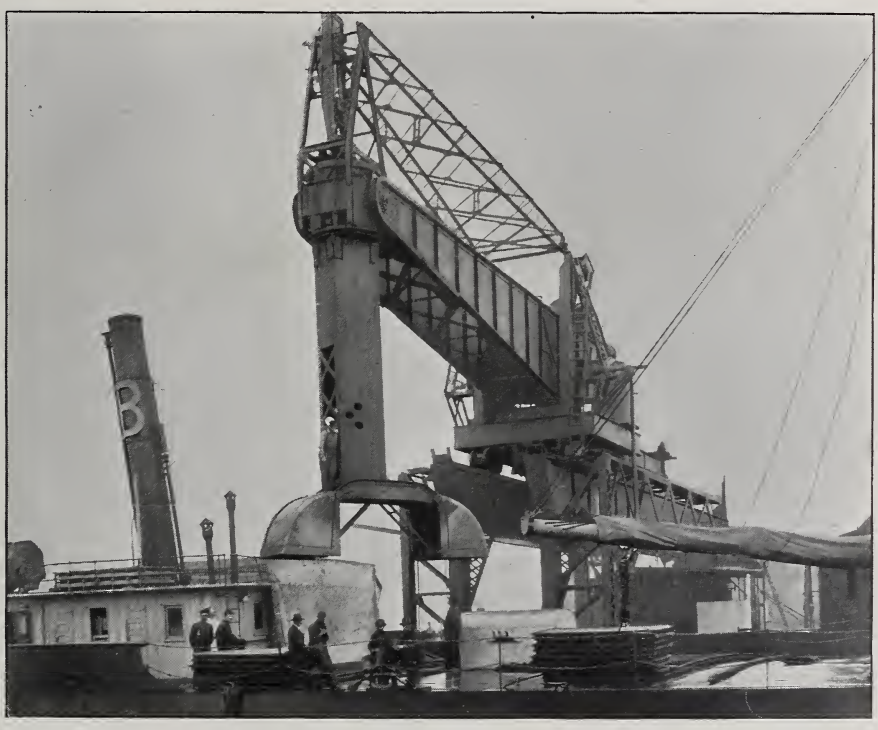
ROPE GUARD FOR HIGH-SPEED CABLES

clean up the floor without tearing up the planking. It is also very flexible in operation, on account of being able to swing through a complete circle, thus being capable of loading a car on the same track as itself, in front or behind it. It is also equipped with a winch for moving cars. The greatest revolution in ore handling machinery that has yet been made will, without doubt, be brought about by the Hulett ore unloader, shown on this page and the one opposite. With all other ore unloaders the buckets are filled by hand, and as the work is very heavy, only the strongest men have endurance sufficient to enable them to work in the close holds of the vessels. These shovelers are paid 14 cents per gross ton for shoveling, so that, assuming a shipment of 18,000,000 tons a year, the cost of shoveling would be $2,520,000. The cost of handling the buckets after they are filled is very small, being, according to figures prepared by Mr. A. E. Brown, from 0.7 cents to 1.37 cents per ton. It was to reduce the cost of shoveling that the Hulett unloader was designed, and in it we find a machine of stupendous power, yet possessing a delicacy of operation that is marvellous. The idea of at-

tempting to build a machine that would do the work that this one accomplishes was certainly sufficient to stagger many engineers; yet, as it appears on the dock to-day, it gives no impression of being gigantic or in the least out of proportion. Its method of operation will be evident from the illustration.

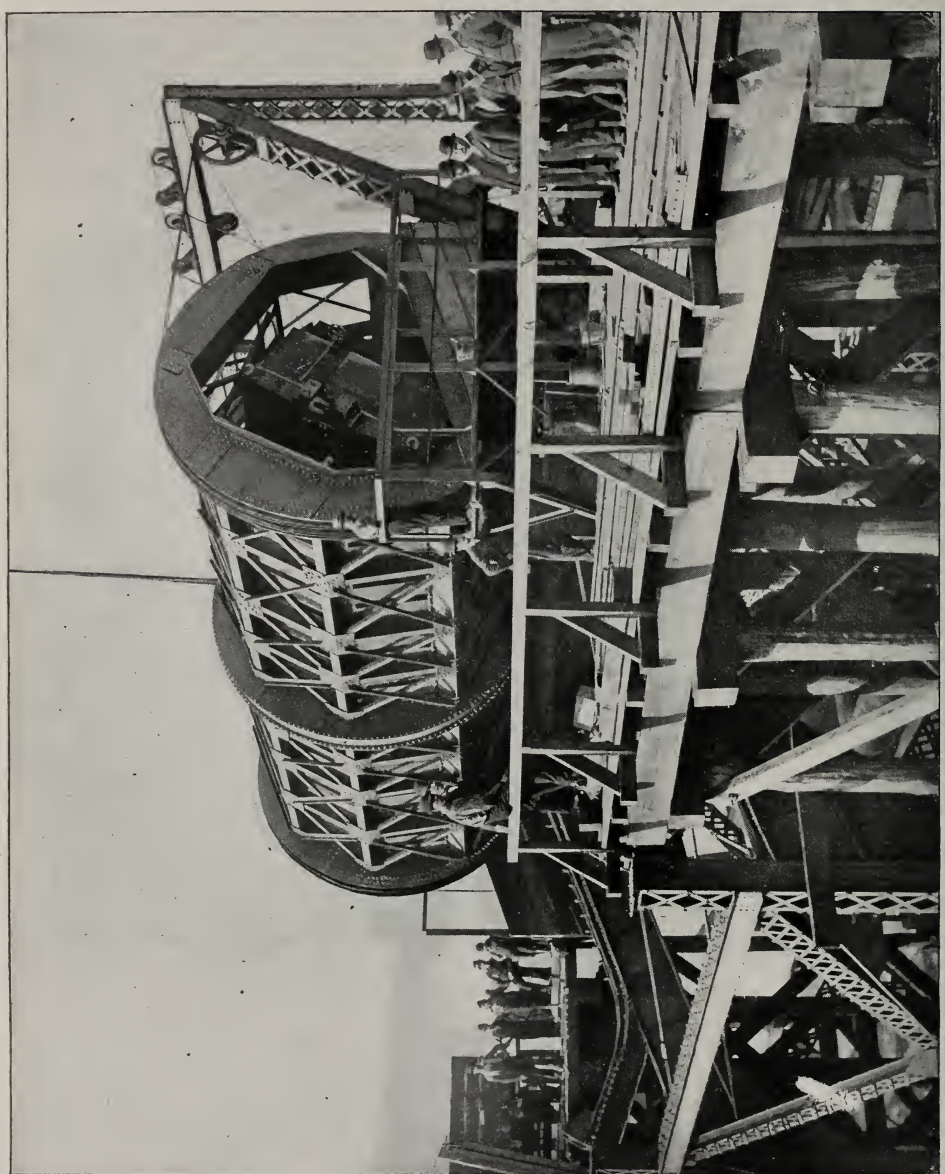
The bucket is of 10 tons capacity, and as there is an unbalanced weight of 20,000 pounds on the bucket end of the tilting beam, it is easily held down to its work. The leaves of the bucket have exerted on them a closing force of 100,000 pounds, multiplied several times through toggle joints, which enables them to close through any soft ore or crushed hard ore.

The tilting arm is raised and lowered by a hydraulic cylinder through four 1¼-inch steel cables, any one of which is sufficient to carry the load. The bucket and its arm can revolve through one and a half revolutions in either direction, and, as the bucket is over 20 feet from point to point when open, it is able to command all parts of the vessel's hold, when hatches are spaced 24 feet from centre to centre. The turning of the bucket and its arm about their centre of rotation is also affected by a hydraulic cylinder. When the bucket is filled and lifted out of the hatch, the trolley on which the trunnion of the tilting beam is mounted is drawn back by a hydraulic cylinder also, and the ore is dumped into a double self-dumping car, carried between the girders. From this car it is dumped into the railway cars, or, if it is to be stored on the dock, into the bucket of an inclined conveyor placed behind the unloader which delivers it to the stock pile.



ANOTHER VIEW OF A HULETT ORE UNLOADER

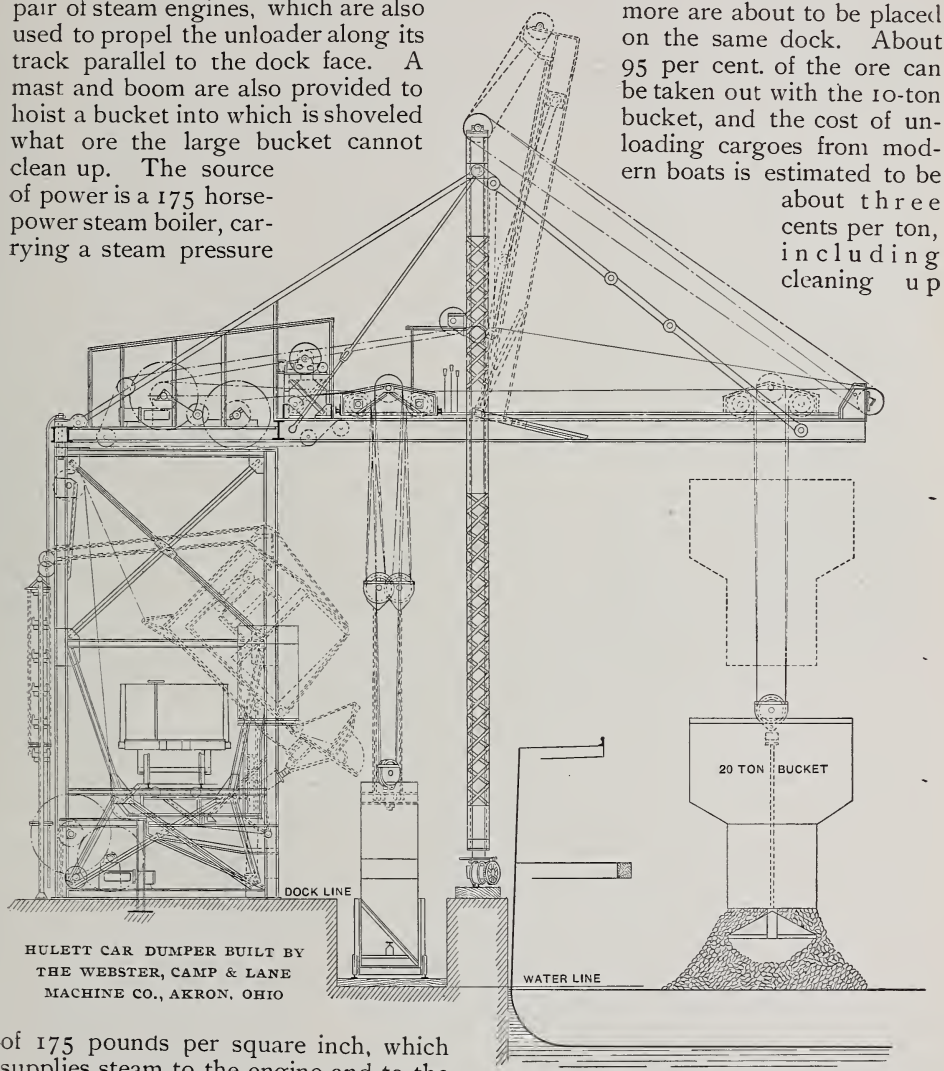
The movements of the four hydraulic cylinders are controlled by one operator, who stands just above the bucket and descends into the hatch with it. One of the best features of the operat·



CAR DUMPER BUILT BY THE EXCELSIOR IRON WORKS CO., CLEVELAND, OHIO

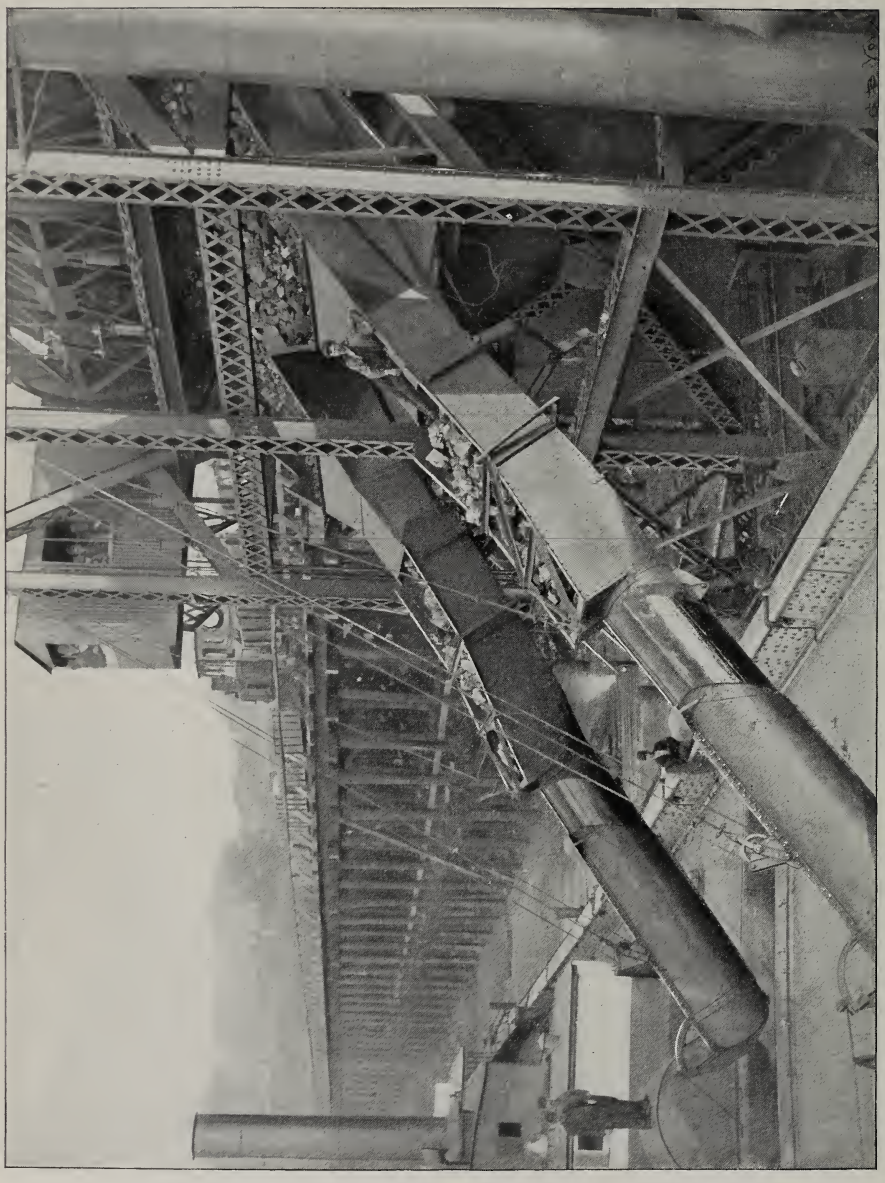
ing mechanism is that when large valves are necessary the operator controls a half-inch pilot valve, whose movements are followed by the main valve. The car between the girders is moved by a pair of steam engines, which are also used to propel the unloader along its track parallel to the dock face. A mast and boom are also provided to hoist a bucket into which is shoveled what ore the large bucket cannot clean up. The source of power is a 175 horse-power steam boiler, carrying a steam pressure of 175 pounds per square inch, which supplies steam to the engine and to the steam pumps, which latter deliver water at a pressure of 1000 pounds per square inch. The steam-loaded accumulator is used to partly balance the weight of the bucket. It requires four men to operate the machine, and three or four men in the hold to clean up the bottom of the boat.

The average capacity of this machine is about 250 tons per hour, so that it will replace at least six bridges of the ordinary type. One is in operation on the docks of the Pittsburgh & Conneaut Dock Company, at Cleveland, and two more are about to be placed on the same dock. About 95 per cent. of the ore can be taken out with the 10-ton bucket, and the cost of unloading cargoes from modern boats is estimated to be about three cents per ton, including cleaning up the bottom of the boat by hand.



HULETT CAR DUMPER BUILT BY THE WEBSTER, CAMP & LANE MACHINE CO., AKRON, OHIO

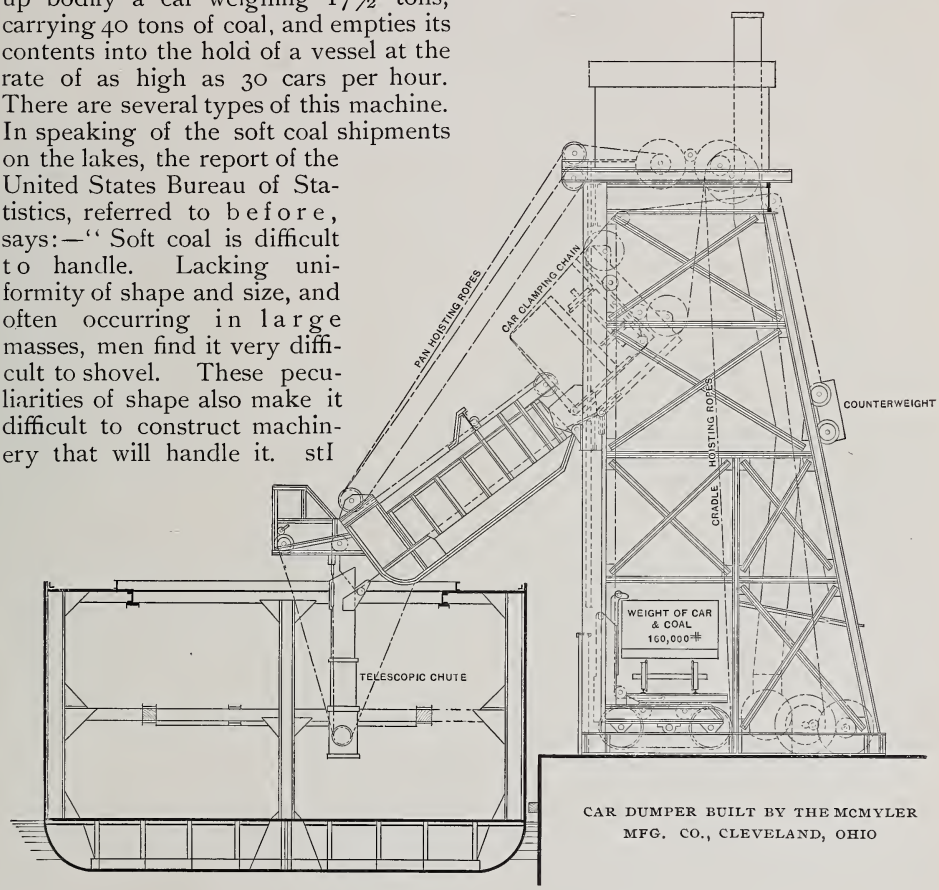
Were it not for the coal traffic westward, the vessels carrying ore eastward would be practically all obliged to return "light"; and, as a matter of fact, most of them do so rather than suffer the delay in discharging cargoes, because the rate paid for coal is very low, for the reason that the traffic westward



ANOTHER VIEW OF THE CAR DUMPER ON PAGE 368, SHOWING COAL AND ORE CHUTES TO VESSEL

is only about one-sixth of that eastward. There is, therefore, always a surplus of "light tonnage" returning up the lakes.

The problem of loading coal has been very well solved in the evolution of the car dumper,—a machine which picks up bodily a car weighing 17½ tons, carrying 40 tons of coal, and empties its contents into the hold of a vessel at the rate of as high as 30 cars per hour. There are several types of this machine. In speaking of the soft coal shipments on the lakes, the report of the United States Bureau of Statistics, referred to before, says:—"Soft coal is difficult to handle. Lacking uniformity of shape and size, and often occurring in large masses, men find it very difficult to shovel. These peculiarities of shape also make it difficult to construct machinery that will handle it. stI



CAR DUMPER BUILT BY THE McMYLER MFG. CO., CLEVELAND, OHIO

physical texture also presents difficulties; it cannot be dropped any great distance without breaking."

A car dumper built for a minimum of breakage is that shown on page 362. Its method of operation will become clear from a study of the illustration. The loaded car is overturned, and its contents are dumped into six buckets carried on a transfer car. The buckets are picked up by either of two overhead travelling cranes and are run out over the hatch and lowered down into it. The bucket is then drawn away, and the coal is deposited in place by passing through drop bottom doors in the bucket. For fragile coals this machine is specially well adapted, but it is necessarily slow in operation.

In the machine shown on page 369, gentleness of handling the coal and speed of operation are very well combined. It is simplified by having only two buckets of a shape well adapted for entering a vessel's hatch, which enables them to be handled almost as fast as the cars can be dumped. The booms on which the waggons carrying the buckets run are pivoted on top of the machine, and the shear legs travel on circular tracks centered about these pivotal points, and thus any spacing of hatches is commanded, and the booms, once

placed, do not have to be moved again till a change of hatches is made. This machine has made possible the shipment of a grade of coal so fragile that the breakage in loading it through pockets was so great as to render it unmarketable.

A faster type of car dumper is that shown on page 371. In this the car is carried up to a sufficient height to discharge the coal on a flat apron, from which it is discharged into the hold of the vessel through an adjustable telescopic chute. The hinge point of the apron may be raised or lowered to suit any height of vessel, and wherever that point may be the cradle begins to overturn on striking it. This makes the machine very flexible. The mechanism for clamping the car is very simple, being simply four counterweights suspended on chains, which wrap around the car as it is overturned. One of these machines recently loaded a cargo of 5176 tons of coal in ten and one-half hours, at a cost of $13, or a per-ton cost of one-fourth of a cent.

A modification of the machine just described is shown on page 365. With this the contents of the car are dumped into a pan of 50 tons capacity, which is partly tipped to meet the overturning car, and while the car is being lowered and another one brought into the machine, the pan is elevated to a sufficient height to discharge its contents into a chute through which the coal is lowered into the boat. A remarkable feature of this machine is that all the operations of overturning the car, and of hoisting and tipping the pan, are performed by a single pair of 16" x 18" engines, the necessary clutches being operated by steam cylinders.

The first successful car dumpers were of the "end dump" type,—a design which requires special cars. They met the requirements of their time very well, however, and the original two are still in operation. A novel design is that shown on pages 368 and 370. The loaded car is pushed into a cylinder which rolls over and discharges the coal into an apron ending in two chutes. This machine is a very fast one, and well adapted to its peculiar location on a high river bank, but the fall of the coal is considerable, as can be seen.

Switching arrangements and storage capacity for loaded and empty cars affect the speed of the car dumpers considerably. Some of the yards have the loaded cars stored on tracks having a down grade into the machine, so that, to get a car on the cradle, it is only necessary to give it a start with a pinch bar, the brake being relied on to control its speed. This is a very convenient, but dangerous, arrangement, as the loaded cars sometimes get started by accident and run into the machine while the cradle is up. A better arrangement is to deliver the cars by a down grade to a haulage mule, which will then bring the cars up an incline into the machine.

Car dumpers are often used for coaling vessels, but this class of work is too small for them, and docks that do a coaling business are generally equipped with some form of coal pocket placed at a sufficient elevation to discharge the coal through chutes into the vessel's hatch.

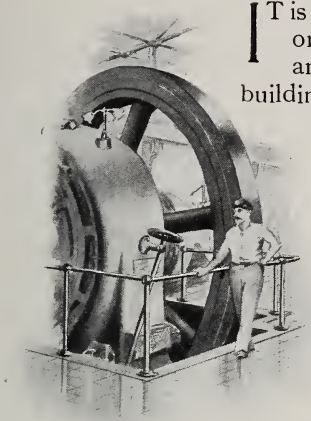
When we consider the rapid development of dock equipment on the lakes, it is often startling to find such highly improved and expensive machinery on very poor and entirely inadequate foundations. The pile dock,—using the word dock in the American sense of pier or landing to which a boat ties,—has long been the universal practice, and not until recently has there been any disposition shown towards permanent structures. Several types of recent construction, however, promised to be the commencement of great improvements in this direction.

In the development of dock machinery on the Great Lakes we simply have another example of the great idea that is the foundation of American commercial methods,—that of building special tools for special work. The modern dock equipment is one of the great "machines" whose efficiency contributes its share towards making it possible to manufacture steel cheaper in the United States than in any other country in the world.

ELECTRICITY IN LARGE CITIES

ITS TRANSMISSION AND DISTRIBUTION

By W. S. Barstow



IT is well within the memory of all when the announcement of the building and equipping of an electricity supply station began thus, — "This model, up-to-date plant is completely equipped with apparatus providing for the highest economy in operation," etc., — a clause only to be repeated another year when a totally different design of plant for the same purpose was described. These repeated changes in the design and equipment of generating plants were sometimes dependent upon the individual ideas of the constructing engineer, and it was often found that after the plant had settled down to a commercial basis, the novelties were thrown aside and the results in efficiency were but little different from the older type of central station. This was largely due to the fact that the improvements were designed for certain conditions, and that these conditions were not developed in actual practice.

At last the designing engineer began to appreciate the fact that the most modern and completely equipped electricity supply station, theoretically an engineering success, was of little value until business enough had been provided to bring about the conditions best suited to its economical operation. In other works, the industry reached such a stage of development where its future progress remained in the hands of the public. In order, therefore, to increase the commercial value of the plant, the sale of electric current was forced by the introduction of the electric motor, which, however popular to-day, was in the field many years before it gained a position occupied by the smallest steam engine.

Close upon the introduction of the stationary motor came the experimental and then final adoption of the railway motor and the development of an electric system for street railway propulsion which soon necessitated remodelling to some extent of the previously constructed supply stations. Then came a rapid growth in the demand for electric current, not only for street railway work, lighting, and stationary motor supply, but for use in every branch of science. Then it was that the public began to appreciate that electricity was no longer a luxury, but an absolute necessity.

In the meantime, in order to supply energy to the public in different localities and under different conditions, there were developed what may be termed four standard types of electricity supply systems:—

(1) The alternating current, because of its ready transformation, was introduced where the demand was in scattered territory; (2) the three-wire, or low-tension, direct-current system, for the supplying of energy in built-up territory; (3) the high-tension, direct-current system for the supplying of arc lamps; and (4) the 500-volt, direct-current street railway system.

As long as these four systems were operated separately from different plants, employing different types of ap-

paratus, the growth in the size of units was necessarily slow. The consolidation of interests, and the development of the multiphase transmission system, however, quickly changed these conditions. By the use of such a system it became possible to generate one class of energy from one type of apparatus, and, by varying the design of the transforming device, adapt it to the supplying of any of the four systems mentioned above. This revolution in the art of electrical supply was far reaching, and consolidation of different interests followed in rapid succession, a means having been furnished whereby additional economies could be secured. This not only brought about the discarding of almost all the former electric generating plants, but often rendered the steam part of such plants of little use on account of the size of the units.

By the combining of the different systems upon one generating plant the load factor was suddenly increased, so that there was at once warranted an increase to a very large extent in the size of the generating unit, and to-day the 5000 H. P., three-phase transmission unit, with its accompanying substations, is the latest development in electric central station engineering. This change affected not only the supply companies, but also the manufacturers of the apparatus which they were using. Engine builders, heretofore supplying a demand for units up to 1000 H. P., were suddenly called upon to enlarge their shops, re-design their tools, and be prepared to meet the demands of units of four times the capacity. The electrical manufacturing companies were called upon to develop transforming devices of a size formerly employed for the primary generating units. Rotary transformers, three years ago a novelty, are to-day standardised in units of 1000 H. P., while static transformers have suddenly grown to enormous proportions.

Further, the growth of the transmission system meant the centralisation of enormous energy in a single plant, passing through a single switchboard, and in the hands of few attendants. While the probability of accident was decreased by the employment of large slow-speed units, it was necessarily increased by the employment of high voltages and by the handling of large power.

The fact that the entire energy on these units must be controlled from one central point, and that that central point must be located and arranged with a view of simplicity and reliability, at once introduced new electrical and mechanical problems, and in the development of switch mechanism and automatic cut-out devices new difficulties arose, due to the fact that the power to be handled was so large that an experiment under actual conditions was almost impossible without serious interruption to the service. To offset this partial sacrifice of reliability, the storage battery was pushed to the front, and, for years struggling along under a plea of efficiency, was suddenly given a new lease of life in its new position as bondsman for continuous and reliable service.

If in a large city an electricity supply business could be started with a fair demand at the outset, without passing through the preliminary stages of gradual development and growth, the question as to the system to be used and the details of construction would not be an especially difficult one.

A universal generating plant of any kind, furnishing energy readily adaptable to all classes of distributing systems, possesses not only great engineering advantages, but is the only means whereby the highest economy can be secured. Several stations operating non-interchangeable systems can never reach the minimum cost in the production of energy. One station, or even two stations, one operating continuously and the other during the maximum load or peak period, can at once develop the highest economies.

However, the best constructed plants without the proper conditions of distribution are always at a disadvantage, and the commercial as well as the engineering problem should be carefully considered. The main generating plant should be erected as near the field of supply as possible, but in a locality of cheap and extensive real estate, best

suited to the economical handling of coal and the securing of good water for boiler feed and condensing purposes. A factory district is preferable to a residential one on account of the objections which might arise in the latter from a possible smoke nuisance, vibration, or noise. Such a location in most large cities can be secured within a distance not exceeding eight miles from the centre of electrical distribution.

Having once located the primary stations with reference to the average territory to be supplied, a very careful commercial survey should be made for the distributing system. An engineer cannot judge the local conditions of a city by passing through it on a railway train, but should live in the place until he becomes thoroughly familiar with the values of real estate and habits of the residents, and well posted on the plans of future growth for which the city might have provided. As a city carefully plans for the future in the laying out of new streets and the erection of new school houses, as well as other public improvements, so the engineer must plan his distributing systems, not alone to answer the present, but also the future, needs of the public. All classes of supply should be taken into consideration, not only the lighting and stationary power business, but also the railway and any other possible uses for the energy. The location of a generating station is a simple problem in engineering economy, but the detail plans of the distributing system necessitate thorough knowledge of local conditions.

Having become acquainted with the problem of general distribution, the question of location of substations and the selection of distributing systems arises. The experienced engineer knows that for a thickly populated and built-up district, devoted to business interests, and where underground construction is necessary, the standard three-wire, low tension, direct-current system is best suited for the purpose, while in scattered sections and in less built-up territory alternating current distribution may be more economically employed. The question, however, which will be of paramount importance to the engineer from a commercial point of view is how long it will be before the scattered section will grow into a built-up business district, and how such change would affect the distributing system.

In the laying-out of a city, provision is made in the location of streets, sewers, and other public improvements for the building-up of any portion, and the object to be kept in view in the designing of an electric distributing system should be the same; that is, the systems of the substations should be so designed that ultimately it should be possible to interconnect them, supplying an entire network from several substations at different points of distribution in the same manner as employed in the systems of water and gas of to-day. Such an arrangement permits of the substation being operated at its highest efficiency.

The primary generating plant of a substation system should be of the three-phase type, as it is used almost entirely for transmission purposes, and the voltage of the generators should correspond to the voltage of the line up to a limit of 10,000 volts, which can be handled directly on the switchboard and which will be a sufficiently high pressure for all city transmission purposes. The steam plant should be built with an idea to permanency and reliability. The generator for high voltage should be of the revolving field type, and a small storage battery should be maintained in the field circuit to provide against the effect of an accident to the exciters and to steady the exciting current.

The switchboard should embody simplicity and safety in its design, as well as provide for every piece of apparatus necessary to economically operate the plant. All the details of the board should be fireproof, and so arranged that an attendant can operate the different devices easily and quickly without exposing himself to high-pressure currents.

The substation should be located as near as possible to the centre of its system of distribution, and should consist of a simple fireproof structure, amply

provided with the proper facilities for ventilation and lighting. The contents of a substation will depend upon the form into which the primary energy is to be converted for use on the distributing system best adapted to the district surrounding this substation.

There are to-day in practical use four systems of distribution, one or all of which can be supplied from a single substation, merely requiring the proper transforming devices as connecting links to the primary energy. The three-wire, low-tension, direct-current system requires for its conversion, besides the step-down transformers, rotary transformers which commutate the alternating current. The potential regulators are inserted between the rotary converter and the static transformer, and are generally of the induction type, affecting the alternating current before it enters the rotary transformer. Often the regulation is attained by cutting in and out coils of the static transformer on the primary side, and sometimes, where special regulation is required, both methods are used.

The alternating system of distribution, when the primary energy is of a periodicity of thirty-five cycles or more, requires a simple step-down transformer to reduce the primary voltage to a point necessary for the safe distribution of current in public streets. Where the periodicity of the transforming current is less than thirty-five cycles, motor-generators or frequency changers are employed to give the same results for the distributing system.

Where it is found advisable to install a high-tension, series-arc system, motor-generators are generally employed, the motor being supplied from the transmission energy and the generator supplying the outside distributing system. Often it is found advisable, on a frequency of 40 cycles or more, to use a high-tension, series-arc alternating system, and then regulating transformers are required between the transmitted energy and the distributing system. Where current is supplied to a railway system, the same type of apparatus is used as for the three-wire, low-tension, direct-current system. By the installation of these different pieces of transforming apparatus the transmitted current from the primary station can be received in the substation over a single set of wires, and distributed from the substation in any form required by the customer.

After the details of the substation have been carefully considered, and the proper type of transforming and distributing apparatus has been arranged for, attention should be given to the question of storage batteries, not as a means of economy, but as a means of insurance against poor service. If it is decided that conditions would warrant this expenditure, batteries should be located at points best suited to the low-tension distributing system. When installed in a standard substation in connection with static and rotary transformers, they will at once protect all types of distributing systems, as by discharging through the low-tension rotaries and static transformers, it will be possible to deliver high-voltage energy to the transmission system, the periodicity being controlled by the speed of the rotaries which can be independently regulated. Thus the storage battery for a short time can supply all systems, high or low-tension, the exact length of time depending upon the efficiency of the transforming devices.

Of all the machinery installed in substations, the rotary transformer can probably be applied to the greatest number of uses. When operated as a converter, it transforms either direct current into alternating, or alternating into direct current. Should a pulley be used on the shaft, it can be used either as a generator or a motor, at the same time delivering the balance of its capacity in direct or alternating current. Thus it can be seen that the entire system of substations, independent of the generating station, is very flexible, it being possible to secure almost any result by operating the transforming machinery either as receiving or transmitting apparatus.

In the final completion of a large transmission and distributing system, the importance of recording meters

should not be overlooked. It should be possible, by proper recording watt-meters, to at once ascertain the energy delivered to, or transformed for, any part of the system. In this way the operating attendants will become accustomed to keeping the different stations and substations at their highest efficiencies; without the use of such guiding apparatus, they would often be at a loss when it is desired to obtain the most economical results. All energy as generated on the primary system should be metered, and each substation should be equipped with a set of receiving and delivering meters, the receiving meters recording the energy entering the substation, and the delivering meters recording all energy after it is transformed for the distributing feeders. Special attention should be given to recording battery meters, so that the rate of charge and discharge may be so regulated as to secure the highest efficiency when such batteries are used outside of the period of emergency.

After a large system is once in actual operation, it is not unusual to find that many unexpected things occur. A sudden short-circuit or accident to the system under certain conditions produces the same result as a water hammer in a hydraulic system, the electric pressure for the instant often doubling the normal operating pressure on the primary system. In large systems at present operated spark gaps have been placed at frequent intervals, and a discharge across these gaps, set for 12,000 volts, has often occurred with a normal pressure of 6000 volts. On this account the danger of using too light insulation in cables and apparatus can easily be seen. All cables, of whatever description, used on the high-tension part of the system should have double insulation, that is, the insulation between each conductor, and ground should equal the insulation between each conductor, and not around each conductor. All generating and transforming apparatus should be tested with a puncture test of from twenty to twenty-five thousand volts, and a continuous test of fifteen thousand volts for one hour when such apparatus is used on a 6000-volt system. A higher test than this will often strain the insulation so as to render the apparatus and the cable weaker after the test than before.

In the installation of cables, generating and transforming apparatus, switchboards, etc., in connection with the high-tension transmission part of the system, it should always be remembered that at some time it will be necessary to do work on the system without interrupting the supply, and for this reason it is often advisable to install duplicate cables and divide the switchboards into two parts, either one of which can be used in conjunction with a duplicate cable system. In this way no trouble will be experienced should it be desired to connect new feeders to the system or make any repairs without interrupting the service.

In a large city supply system attention should be given, not only to the study of the commercial and mechanical details of construction and design, but also to the conditions under which such a large system will be expected to operate. The one question of coal supply is in itself of vital importance. In years past the item of coal, compared with the total operating expenses of the plant, was a small one. Modern development of large transmission and distributing systems has enlarged the problem, until to-day it is of the utmost importance. Stations using 300 tons of coal per day are at present in active operation, and the method not only of handling this quantity of coal in the station, but of purchasing it, is of great importance.

Almost all the coal mines are controlled to a greater or less extent by the railways connected with them, so that often the supply of coal in a distant city becomes a question of transportation. Formerly a coal reserve sufficient to last two or three weeks was maintained by the electric supply company, thus making it possible, should a difficulty arise in securing coal from the contracting party, to go out into the open market and purchase coal until the old contract could be adjusted or a new one made. In the case, however, of a large con-

sumption of coal, reaching several hundred tons a day, the carrying of reserve stock for even two weeks becomes more of a problem, and the matter of securing within that time a means of continuing a steady supply is still more serious. What this problem will amount to when the coal consumption of a large system reaches seven or eight hundred tons a day, it is difficult to say, unless in some way the responsibility be shifted to the transportation companies handling the coal at the mines.

Still another question will arise after the completion and starting of a large transmission distributing system. This is the matter of providing for future capacity. To-day when estimating upon the requirements of the future, consideration must be given not to the demands of a few weeks hence, but to the requirements for many months to come. When station units were of about 1000 H. P. capacity, little difficulty was experienced in securing a sufficient number of contractors to undertake the work without delay. With units of 5000 H. P. capacity, prompt delivery is more difficult to secure, since there are few contractors equipped for this class of work, and the securing of the raw material becomes more of a problem. The manager of a large system is, therefore, obliged to live in the future rather than in the present, although he must always be prepared to secure the highest economies under the present rather than the future conditions.

As consideration is given to the past and present progress of the electricity supply industry, the question of the future naturally arises. What the final outcome will be it is impossible to predict, but that the size of the generating unit will continue to increase from 5000 H. P. upwards is a foregone conclusion, the ultimate size of such unit depending only upon the conditions of manufacture and cost of operation.

The sudden appearance of a new and more direct method of securing the energy at present supplied by the steam generating unit is very doubtful, since almost all past efforts have finally terminated in an endeavour to further increase the efficiency of the steam engine.

Whatever improvement will be made in generating energy will be likely to come about in the mechanical conversion of the steam. What this improvement will be it is difficult to predict at the present day, but the development of the steam turbine is certainly encouraging.

That this apparatus is capable of attaining as high economy as the steam engine proper of to-day has been practically demonstrated; its high rate of speed at once reduces the size and cost of the unit and at the same time economises real estate, thus overcoming some of the important difficulties in the increase of the size of the reciprocating steam engine.

The electrical part of the system has developed by such rapid stages that its efficiency has already reached a very high standard, but the steam portion has continued to supply the mechanical power at much the same figures as it did many years ago. The reciprocating steam engine of the present day must surely fall to the rear in the onward march of electricity supply, and what new impetus the industry will then receive can hardly be foreseen.

CARTING CANE TO THE MILL

SUGAR ENGINEERING IN CUBA

By E. Sherman Gould, M. Am. Soc. C. E.

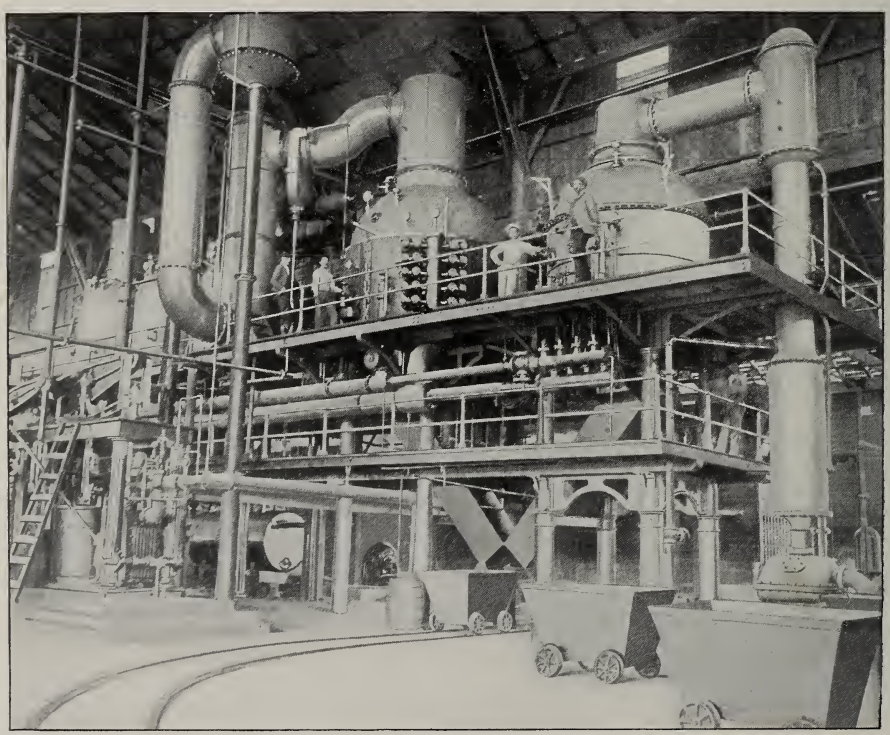
NOT long ago a leading engineering periodical made somewhat mocking comment upon the establishment of a course on "Sugar Engineering" in the curriculum of one of the technical schools. This, however, reflected more on the periodical than on the school; in point of fact, it would be hard to find an industrial operation involving more scientific and engineering details than that of sugar-making. It stands fully abreast of iron and steel production. It is the object of this paper to give a brief sketch of the various processes through which, in particular, Cuban sugar-cane passes, in order that its juice may be extracted and converted into "96 per cent. centrifugal."

The sugar-cane of Cuba is not replanted each year. Frequently one planting will produce crops for seven, ten, and even more years in succession. Land which requires replanting oftener than every five years would be unprofitable for sugar raising. Replanted cane requires fifteen months from planting to sugar making. The yield of cane per "caballeria," which represents an area of about 33⅓ acres, varies. In some plantations it has reached 100,000 "arrobes," the arrobe being a weight of about 25⅓ pounds. This is equivalent to nearly 40 tons of 2000 pounds per acre. The average production of good plantations is, perhaps, from 20 to 25 tons of cane per acre. The average yield of "first," or 96 per cent. sugar, is not over 8½ per cent., although in some cases it has reached 10 per cent. of the weight of the cane, or, say, from 1¾ to 2¼ tons of sugar per acre. Sugar is frequently reckoned in bags, the bag containing from 300 to 325 pounds. This would give, as the average production of good plantations, something like fifteen bags per acre.

Good cane contains about 90 per cent. of its weight of juice, or "guarapo," and the object of scientific sugar making is to extract and utilise as much as possible of this juice. About 75 per cent. is as much as practical science has as yet been able to secure, or, at the very outside, 70 per cent. of the total weight of the cane. This guarapo may contain about 15 per cent. of extractable sugar, which will bring us back to the 10 per cent. of sugar obtainable by the best modern processes from the best Cuban cane.

The "Zafra," or season of cutting and grinding the cane, is a period of intense activity. It commences about

CANE CARTS AWAITING TURNS TO BE WEIGHED



THE INTERIOR OF A "CENTRAL" SHOWING VACUUM PANS AND CONDENSERS IN FRONT; TRIPLE EFFECT IN REAR, AT THE LEFT; BEAM PUMPING ENGINE IN FRONT, AT THE LEFT; AND SUGAR COOLING WAGGONS IN FRONT AT THE RIGHT. INSTALLED BY THE KRAJEWSKI-PESANT COMPANY, NEW YORK

December 1 and lasts about five and one-half months, or until about May 15. During this time work proceeds day and night, for the cane must be ground as fast as it is cut, and should be cut as fast as it can be ground. The best practice is now admitted to be the separation of the two processes of raising the cane and making the sugar. This has led to the establishment of vast central stations to which cane is brought to be ground, being very commonly paid for in sugar, one-half the production or of its value being a usual rate.

fact, already stated, that replanting occurs only at widely separated intervals, so that the principal work is confined to the few months of cane-cutting. There is, therefore, a short period of intense activity when it is difficult to secure the necessary labour, followed by a longer one of comparative idleness, when only enough help is retained for the indispensable cultivation of the fields between crops. Without this they would rapidly deteriorate. It may be here remarked that the agricultural features of sugar making are greatly behind the

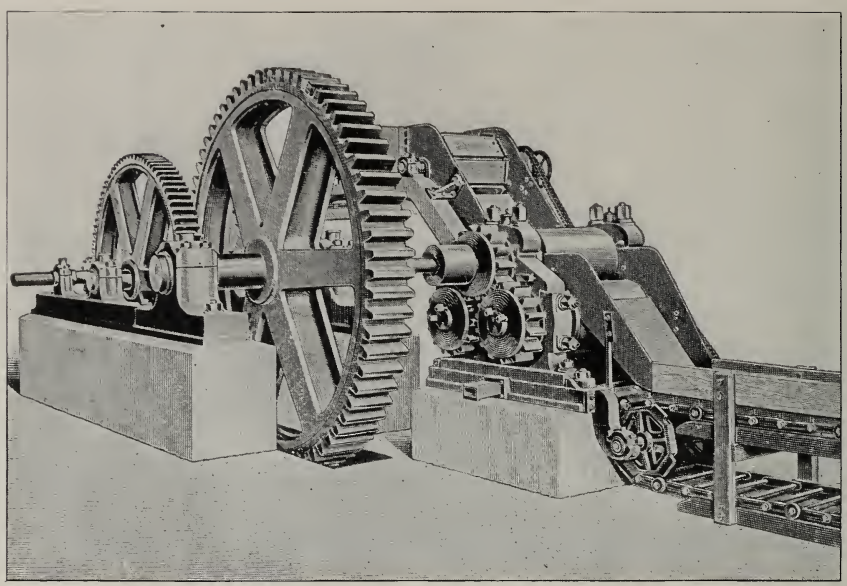
A TYPICAL CUBAN SUGAR "CENTRAL"

The manner and conditions of raising the cane under this system are peculiar and somewhat complex, as there is considerable variety in practice. Of course, all contained in this paper refers to conditions previous to the recent war in Cuba. What the practice may be in the future it is impossible to foretell, but it is safe to assume that it will be closely modeled on that of the past.

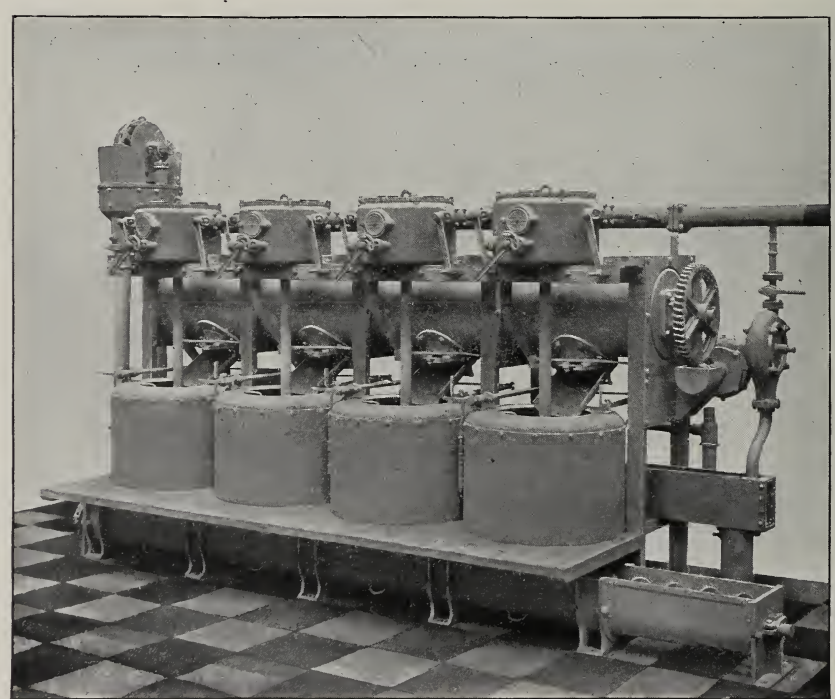
In many cases the land on which the cane is produced is owned by the proprietors of the "Central," and is rented or farmed out to the cultivators. The peculiar features of the cultivation and gathering of the crop consist in the mechanical ones, and there is room for much improvement in this direction.

The general system of work is that of the "colónia," or colony. In this the farmer hires help which he colonises on the plantation, providing food and housing for his labourers, as well as paying them a certain wage in money. In these colonies very strict regulations prevail, without which the system would be impracticable.

When the cane has been cut, the next operation is to transport it to the central. At this point the engineering features of the business may be said to commence. Transportation is effected



A SET OF CRUSHING ROLLS MADE BY FRIED, KRUPP GRUSONWERK, MAGDEBURG-BUCKAU, GERMANY, AND LONDON



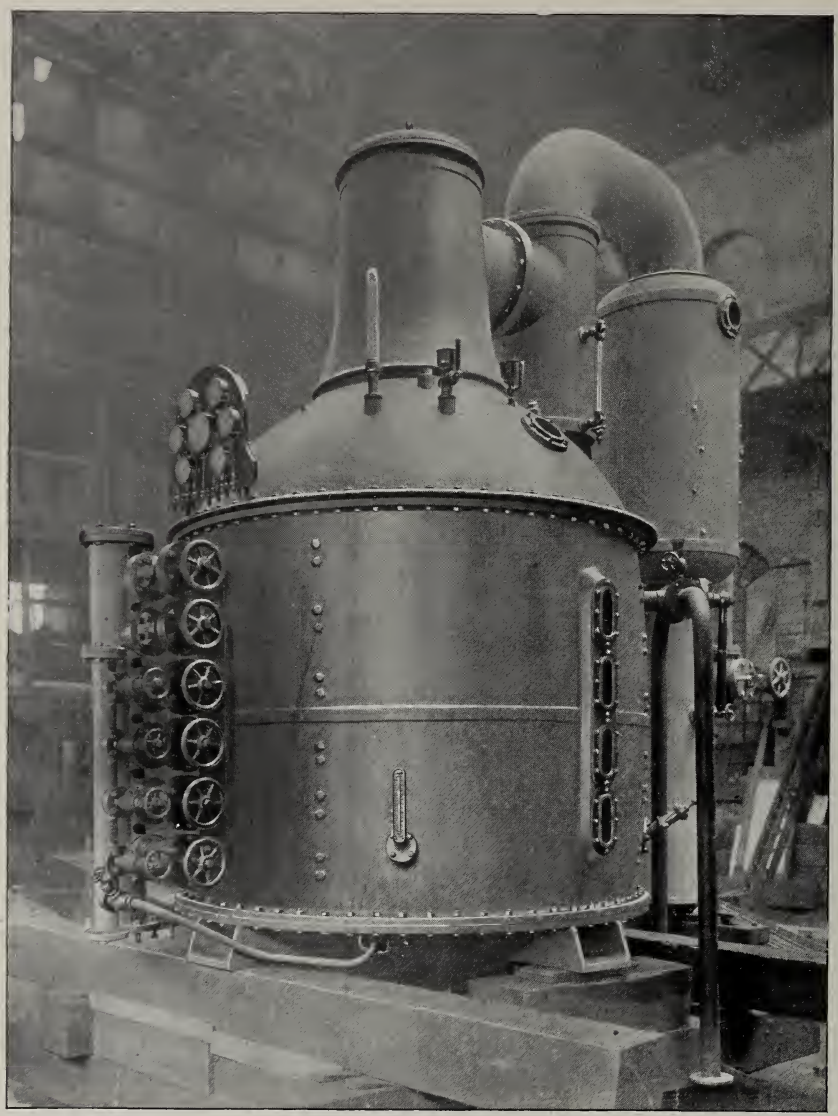
A SET OF CENTRIFUGALS OPERATED BY A WATER MOTOR. MADE BY MESSRS. WATSON, LAIDLAW & CO., GLASGOW, SCOTLAND

mostly upon narrow-gauge railways ramifying out from the central, although much standard way has also been laid. A single "injenio," or sugar works, will sometimes have as many as thirty or forty miles of such railway laid and operated. The cane, having been brought to the mill, is immediately ground. The grinding is effected in the "trapiche," or rolling mill, which consists of three iron cylinders, arranged in triangular, or pyramidal form, two forming the base and the interval capped with the third. The largest trapiches have rollers or cylinders from 6½ to 7 feet in length, with a diameter of 40 inches. They are set from half an inch to an eighth of an inch apart, and run at a very low rate of speed, the rate being slowest in the large machines just mentioned, where it will not reach two revolutions per minute. These large trapiches should grind from 450 to 500 "toneladas" per twenty-four hours, the tonelada, or weight of 1000 kilos, being very nearly the same as the "long ton" of 2240 pounds. At some central injenios as many as 1500 tons, and even more, are ground every twenty-four hours, producing upwards of 150 tons, or, say, 1000 bags of sugar, in the same time. Even larger quantities, up to 2000 bags per twenty-four hours, are claimed in individual cases.

By a single grinding, through one set of rollers as above, a good result is the extraction of 70 per cent. of the total juice contained in the cane, leaving 30 per cent. in the "bagazo." In order to obtain a still larger extraction, the bagazo is frequently passed through a second, and even third set of rollers; but this third grinding is of doubtful expediency. The cane is also sometimes passed through a "desfibrador," or shredding machine, previous to being run through the trapiche. This preliminary treatment seems to be always advantageous, and, coupled with a single grinding with a good trapiche, may result in an extraction nearly equal to that given by a double grinding, or about 75 per cent. of the total juice contained in the cane. When double grinding is practised, it is not attempted to get more than perhaps 50 or 60 per cent., or possibly 65 per cent., on the first operation, the additional percentage being obtained by the second rolling. A certain amount of water is added to the bagazo between the two grindings.

The cane is fed to the trapiche by a

CUBAN PLANTERS



A VACUUM PAN BUILT BY MESSRS. A. & W. SMITH & CO., LTD., GLASGOW

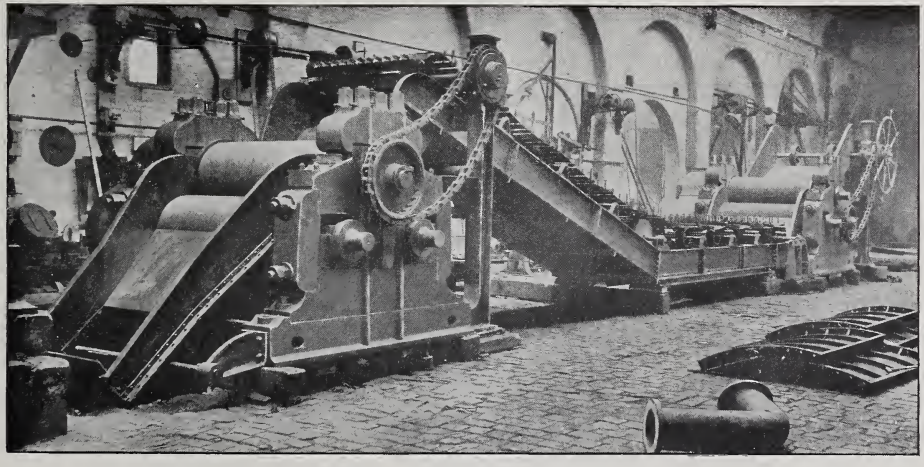
conveyor, or endless belt, upon which it is placed as it is delivered from the waggons. This conveyor, or "conductor," is operated by the same engine that drives the trapiche, and can be regulated, as regards speed, and thrown in and out of gear by suitable contrivances. After passing through the rollers, the bagazo is received upon a similar conveyor and delivered to the furnaces. This bagazo, by means of improved methods, furnishes the entire supply of fuel employed in running the works. A *sine qua non* in a sugar factory is to keep a steady supply of cane going into the mill, in order to furnish a steady supply of fuel to the furnaces. If the mill stops, the supply of fuel stops, steam goes down, and all goes wrong in the factory.

Up to a recent date it was always necessary to partially dry the bagazo

before using it as fuel. When dry, its calorific value is somewhat higher than that of an equal weight of wood. The drying process necessitates a great deal of space, and time to spread and otherwise prepare and transport the material. At present, by means of improved furnaces, or "bagazo burners," the material is burned green, or just as it comes from the conveyor. The introduction of these furnaces, and the consequent saving of time and labour, mark one of the great epochs in the progress of economical sugar making, second only in importance to that of the "triple effect" apparatus. Economy in firing the boilers is one of the greatest desiderata, as will be realised when it is stated that the large injenios require for their operations batteries of boilers of from 1000 to 3000 horse-power.

In the early days of sugar making the juice coming from the mills was passed into a series of "pailas," or boilers, arranged in groups of four, of progressively diminishing capacity and increasing temperature. This apparatus was known as the Jamaica train. It is needless to describe this system more fully, and, although greatly modified as to details since their first introduction, still retaining the fundamental features of the first invention.

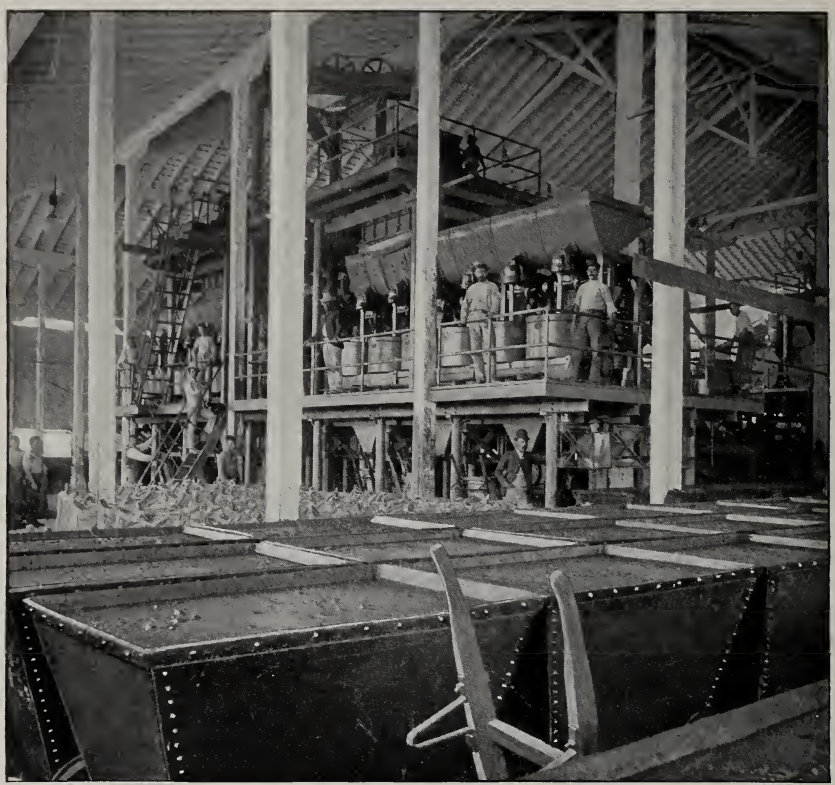
According to present practice, the juice flowing from the trapiche is pumped either directly into receptacles called defecators, or is first passed through an intermediate apparatus called the "calentador," or heater. The object of this heater is to raise the temperature of the juice from about 80° Fahr. as it comes from the mill, to from 100° to 112° by the utilisation of otherwise waste heat, before delivering it to the defecators. The latter are cylindrical copper vessels, with semi-spherical bottoms, placed in cast iron holders or jackets, which leave a space between them and the copper bottom. Into this space steam is admitted and the juice heated. The defecators vary in size, having generally a capacity of from 1000 to 1300 U. S. gallons each, and are arranged in line. A capacity of 1300 gallons (nearly 180 cubic feet) is sufficient to treat the juice obtained from each 100 tons of cane ground in the twenty-four hours.



CRUSHING MILLS BUILT BY MESSRS. A. & W. SMITH & CO., LTD.

because it has been entirely superseded in the best injenios by the "triple effects" of the vacuum process, originally invented in 1840 by Robert Rillieaux, of New Orleans, La., U. S. A.,

While the defecators are being filled to within a few inches of the top, steam is gradually admitted, as above. Before reaching the desired level, a solution of lime is added, and the whole is well



A PURGING PLANT INSTALLED BY THE KRAJEWSKI-PESANT COMPANY, NEW PORK

stirred up. The lime used must be of the finest quality; about 7 to 15 pounds are necessary for a defecator of 1000 gallons capacity. The best temperature at which to introduce the lime is about 190° Fahr. It takes about twenty minutes to fill a defecator, and, with steam of 55 to 60 pounds pressure, in fifteen minutes more, or a total of thirty-five from the commencement of the operation, scum, or "cachaza," begins to form on the surface and the steam is shut off.

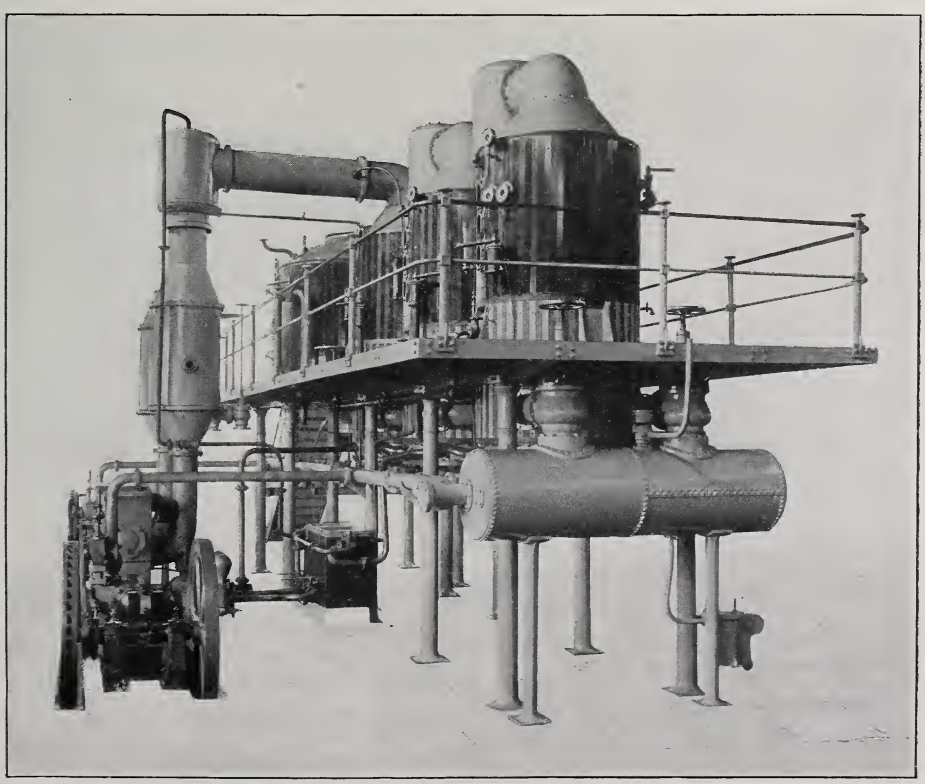
Great care is necessary to carry this operation through successfully. The juice must be sufficiently heated to separate the scum, but boiling must be avoided, or the whole batch would be ruined. When successfully done, the juice is separated into three layers, the lowest being very thick and turbid, composed of precipitates of insoluble salts, earthy matter, lime, etc. The volume of these substances varies much, according to the quality of the cane and the manner in which the defecation has been conducted, amounting generally to from ¼ per cent. to 2 per cent. of that of the crude guarapo. On the surface floats a stratum of scum 4 to 6 inches deep, soft and thick, composed of albumen, lime and woody matter. Between these two lies the purified juice, clear, transparent, and of golden colour.

The whole is allowed to remain ten or fifteen minutes, after which one side of a two-way cock is opened, which allows the turbid fluid at the bottom to be drawn off into a receptacle. When this is done, the direction of the two-way cock is changed and the purified juice is drawn off into a different receptacle until the scum is reached, when that also is drained away separately. The defecator, being now empty, is ready to receive another charge, and

the same routine is repeated. The entire round of operations consumes about one hour for each charge.

The scum and turbid residue still contain a considerable portion of juice, of which it is desirable to extract as large a percentage as possible. To this end the scum is led off to scum kettles,—rectangular iron tanks furnished with serpentine steam pipes. In these the scum is subjected to a defecation similar to the first, with certain modifications. The clear juice derived from this second treatment is added to that obtained from the first. The remaining scum is then passed through a filter press and nearly all of the remaining juice is squeezed out and also added to the previous product. The solid residue, formed in cakes, has some value as a fertiliser.

The grosser impurities of the juice, amounting to about 40 per cent. of its total weight, having been eliminated by defecation, the next step in the treatment is concentration by evaporation. This is accomplished in the triple effect apparatus. The triple effect, the invention, as already stated, of Robert Rillieaux, consists of three cylindrical vessels, into which the purified juice is delivered from the defecators. In these vessels a vacuum is formed by means of a condenser and air pump. Into the first vessel exhaust steam from the engines and pumps is admitted, this containing enough heat to cause the juice to boil, as the atmospheric pressure has been removed. The hot vapours produced by this ebulition are passed over to the heating surface of the second vessel, causing the juice which it contains to enter into ebulition also. The vapours from this second vessel are, in turn, passed over to the heating surface of the



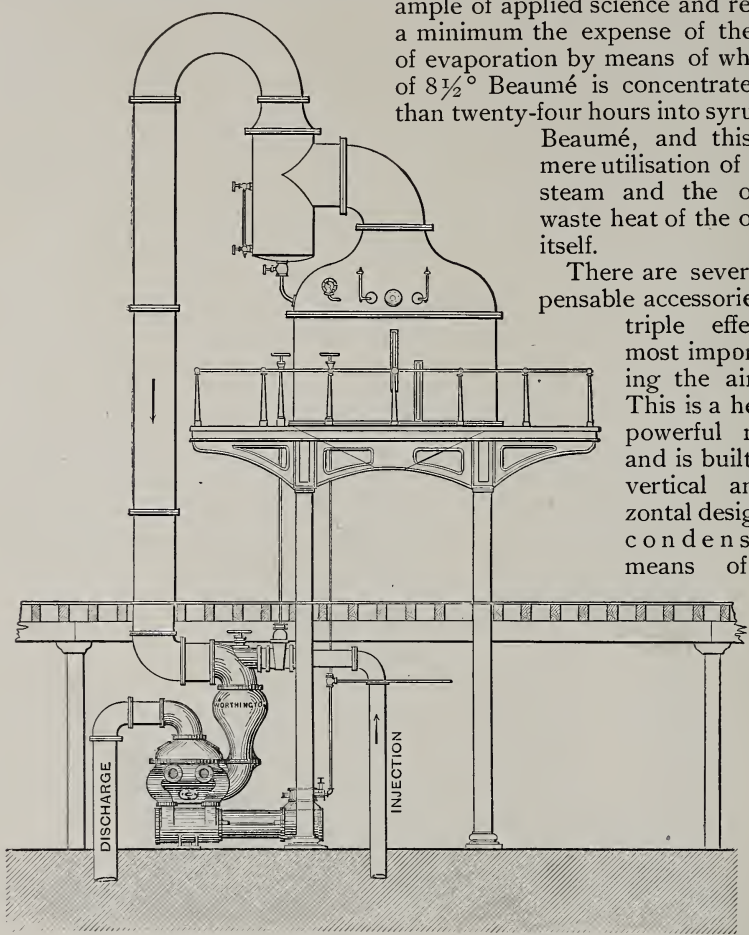
TRIPLE EFFECT, VACUUM PAN, AND PUMPING ENGINE. BUILT BY MESSRS. CAMPBELL & CALDERWOOD, PAISLEY, SCOTLAND

third, with the same result. This series of operations recalls that of the triple expansion steam engine, the object in both cases being the economy of heat.

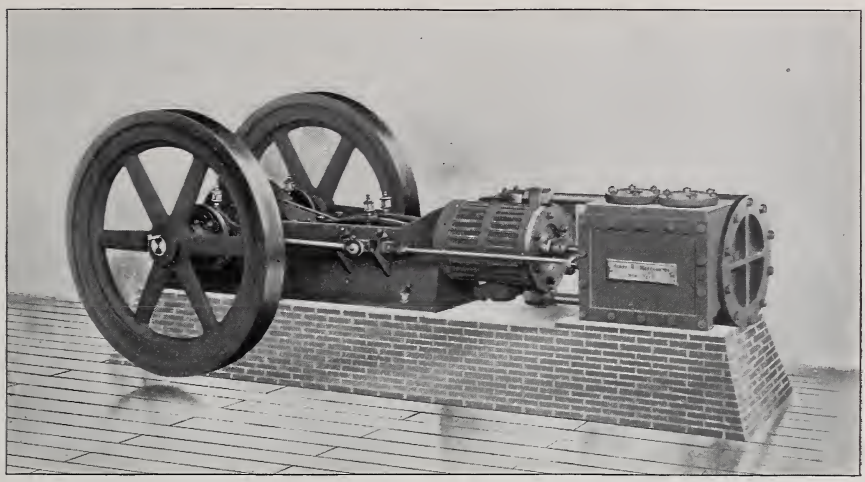
The vessels may have, in the larger installations, a total height, over all, of 16 to 17 feet, the diameters increasing from about 7 feet in the first to 7½ in the second, and to 8 feet in the third, with an aggregate heating surface of about 9000 square feet. These dimensions would be suitable for the treatment of about 16,000 cubic feet of defecated juice per twenty-four hours.

As it is the object of this paper to give merely a general idea of the different processes of sugar making, rather than a detailed description of the processes and the apparatus by means of which they are effected, the construction and operation of the triple effect will not be entered into. Suffice it to say that in its theoretical conception and practical execution, it represents a striking example of applied science and reduces to a minimum the expense of the process of evaporation by means of which juice of 8½° Beaumé is concentrated in less than twenty-four hours into syrup of 23° Beaumé, and this by the mere utilisation of exhaust steam and the otherwise waste heat of the operation itself.

There are several indispensable accessories to the triple effect, the most important being the air pump. This is a heavy and powerful machine, and is built in both vertical and horizontal designs. The condenser, by means of which the vapours from the third vessel of the triple effect are condensed, is another important adjunct. Other pumps are also required. There is one needed to raise the defecated juice from the defecators to the triple effect, and another to remove the condensed vapours and accompanying hot water produced by the action of the condenser from the hot well and deliver them to the cool-



A WORTHINGTON CONDENSER AND VACUUM PAN OPERATING ON THE WET SYSTEM



A ROTATIVE DRY VACUUM PUMP FOR SUGAR HOUSE USE. BUILT BY H. R. WORTHINGTON, NEW YORK AND LONDON

ing tower. These pumps may be independent horizontal engines or worked from the engine of the air pump.

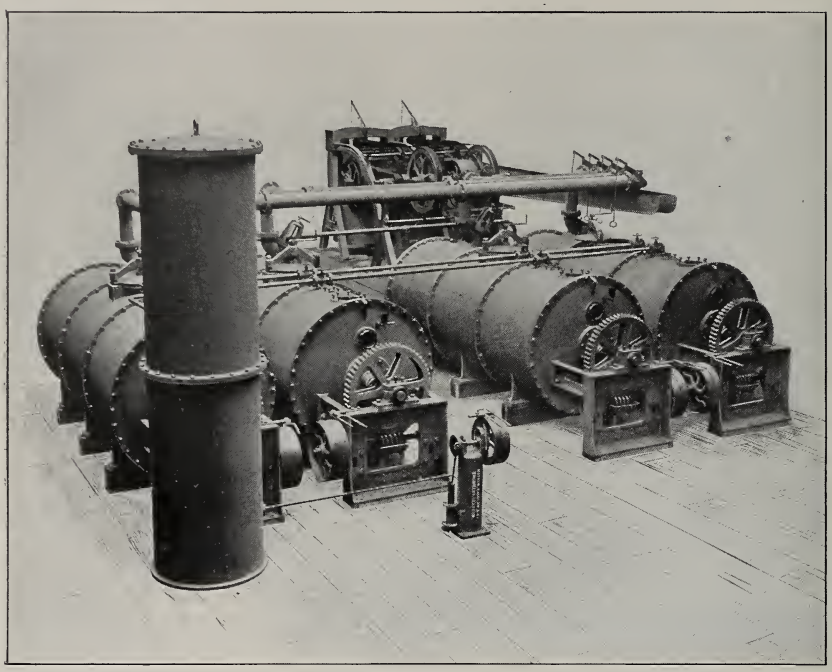
In the triple effect the juice is concentrated from about 9° to 23° or 24° Beaumé, when it becomes "meladura," or syrup. The concentration is not carried any further, so as not to produce a premature crystallisation of the syrup. After leaving the triple effect the syrup is sometimes subjected to a clarification, but opinions appear to differ regarding the advantage of this process. When it is practised, the syrup is run into a clarifier where it receives another boiling and addition of lime, by means of which more scum is separated and removed by skimmers. Either with or without this clarification the syrup is ready, on leaving the triple effect, to be introduced into the vacuum pan to be crystallised.

There are many forms of vacuum pans, all founded upon the same principle of concentrating the syrup to 45° or 50° Beaumé by further evaporation, and then adding more syrup of lower temperature, to produce crystallisation. This addition of colder syrup is continued until the vacuum pan is filled with crystals of sugar, containing also certain impurities and about 10 per cent. of water. The whole is called the "masa cocida" in Spanish, and "masse cuite" in French. There is no English equivalent. Its composition is about as follows: —

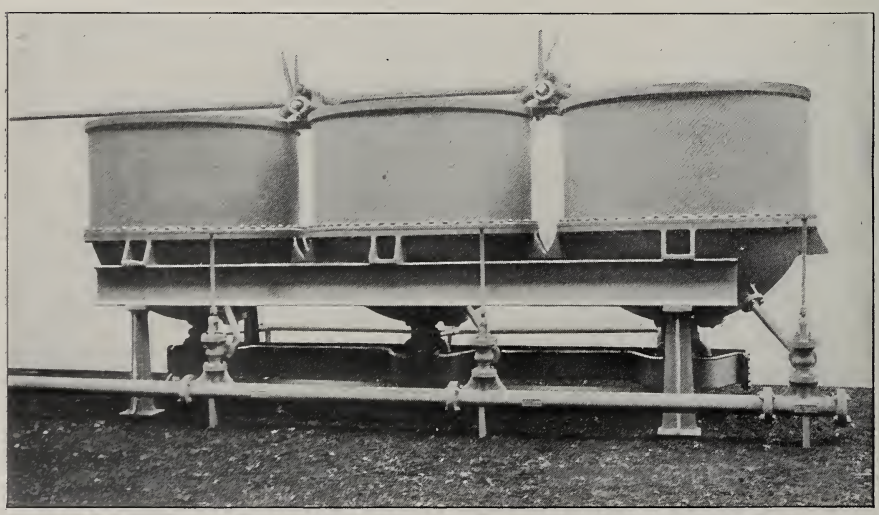
Sugar	75	per cent. to	87	per cent.
Foreign matters	15	"	5	"
Water	10	"	8	"
Total	100	"	100	"

The treatment in the vacuum pans is an operation requiring much skill and experience. It is something like the triple effect process, as far as evaporation in vacuum is concerned; but whereas in the triple effect crystallisation is avoided, in the vacuum pan it is the object sought. The operation may last from seven to eight hours.

The final operation is purging the "masa cocida," by placing it in a suitably designed machine called the "centrifugal," where, by rapid revolution, about 20 per cent. to 30 per cent. of the total mass, consisting of the above-named water, impurities and some uncrystallised sugar, is separated and thrown off as molasses. Before charging the "masa cocida" into the centrifugals, it is first delivered to the "malaxar," or mixer. This consists of an iron vessel traversed by a shaft upon which are blades. As this revolves, the hot mass is stirred up and prevented from becoming set. The mass is either delivered directly from the vacuum pans to the mixer, and fed



A CRYSTALLISING PLANT MADE BY MESSRS. WATSON, LAIDLAW & CO , GLASGOW

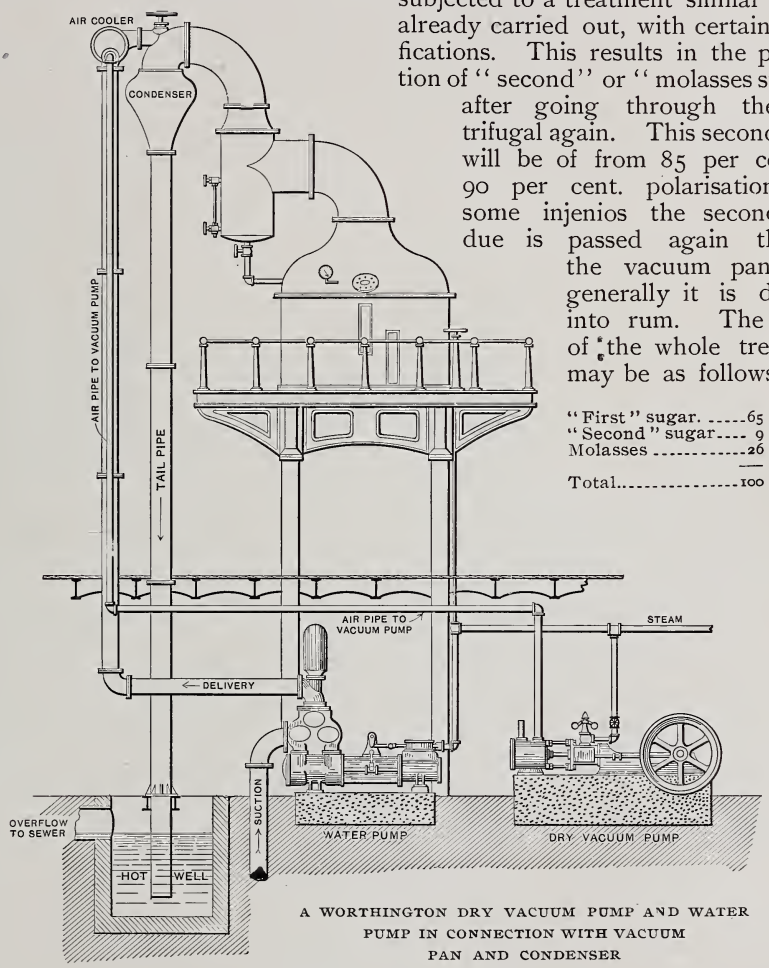


A RANGE OF THREE 600-GALLON DEFECATORS. MADE BY THE MIRRLEES, WATSON & YARYAN CO., LTD., GLASGOW

thence, still hot, to the centrifugal, or it is allowed to stand and cool in the waggons for two or three days before being placed in the mixer. In this latter case the solidified mass is first broken up in a special machine called the "triturador" before being placed in the mixer. This process is called "cold purging."

When the mass is charged in the centrifugal, this latter is made to revolve, at first very slowly, but more and more rapidly up to 1000 or 1500 revolutions per minute. By this rapid motion all the molasses is thrown off in from one to fifteen minutes, according to circumstances, and the motion is then gradually arrested. The sugar that remains is known as "first sugar," of 96 per cent. polarisation, and can be placed at once in bags for the market. It may amount to about 65 per cent. of the total "masa cocida." The residue is placed again in the vacuum pans and subjected to a treatment similar to that already carried out, with certain modifications. This results in the production of "second" or "molasses sugar," after going through the centrifugal again. This second sugar will be of from 85 per cent. to 90 per cent. polarisation. In some injenios the second residue is passed again through the vacuum pans, but generally it is distilled into rum. The result of the whole treatment may be as follows:—

"First" sugar.	65	per cent.
"Second" sugar	9	"
Molasses	26	"
Total	100	"



A WORTHINGTON DRY VACUUM PUMP AND WATER PUMP IN CONNECTION WITH VACUUM PAN AND CONDENSER

This rapid sketch of the processes employed in the production of unrefined Cuban cane sugar and of the apparatus by which they are effected will suffice to show that the installation and operating of a large injenio calls not only for a large amount of money, but also, directly or indirectly, for a great deal of engineering skill, and this without making any mention of the chemical features

of the problem, which also demand skill and attention. The entire series of operations may well be said to constitute a distinct branch of engineering, so that the name "sugar engineering" is by no means a pretentious one to give to a course of study in a technical college.

As regards the commercial side of the question, much might be said, and many figures and statistics quoted. The prosperity of Cuba seems to be mainly centered in her sugar industry, and the success of this industry depends upon the price at which sugar can be made at the works. So far, two cents per pound seems to be the general figure, though less than this is quoted in isolated cases. It is probable that, even with the best appliances and methods now known, the cost of production, f. o. b. at the works, can never fall below one and one-half cents. What further progress may be made in sugar engineering in Cuba, resulting in increased economy, it is impossible to tell, or whether such progress, if made, will be more than that necessary to keep abreast with similar advances which may be looked for in the production of beet sugar, the great rival of Cuban cane sugar. It would seem, however, that the beet sugar industry has reached a higher degree of perfection than that of cane sugar, and that, therefore, further improvements in the former may be expected to come more slowly. There seems great scope for the introduction of improved methods in Cuba, both in raising and harvesting the cane and producing the sugar, and also in reducing cost of transportation. This last factor of transportation affects the price at which 96 per cent. centrifugals can be laid down in United States ports, which is, after all, the final question to be solved.

One thing is certain,—Cuban sugar production, to be profitable, must be on a large scale; large plantations, large colonias, large centrals. It has been shown that the best practice of to-day consists in separating the work of cane farming from that of sugar making. It is quite possible, however, that large syndicates might find it advantageous to revert to the original method of combining the two. Large tracts of unimproved land might be purchased and cheaply brought under cultivation by means of machinery, as is done in the cultivation of the extensive wheat lands of the United States. With the rude appliances now used, the work of breaking up, cross-ploughing, planting the cuttings, etc., costs about $45 (£9) per acre, and although cane can be cut and ground within fifteen months of planting, it may require three years before virgin land is brought up to its highest degree of productiveness. It should be possible to greatly reduce both time and cost, particularly the latter, by the use of improved mechanical means on a great scale. Simultaneously, injenios could be erected, capable of handling the produce of the plantations.

THE WORLD'S COAL

FACTS AND FEATURES OF THE PROBLEM

By Benjamin Taylor, F. R. G. S.

NO single commodity has the same wide industrial, commercial, social, and political interest as coal. It enters more or less into the daily occupations, habits, thoughts, and needs of every member of every civilised community. It is the source of wealth both in the getting and in the using, and though it has been called "bottled sunshine," it has been the cause of some of the darkest days in the history of human industry.

'Tis coal, not love, that makes the modern world go round, and that nation must lead the others which has cheap coal, good coal, and plenty of it. Up till now this has been the position of Great Britain. Some countries have cheaper coal; but, after all, very little profit is to be got by comparing the cost prices at the pit-head in the several producing countries. To use a hackneyed form of expression, there is coal and coal. The indignant housewife knows that there is coal and a slatey substance which passes,—and is charged for,—as coal. There is no comparison, for instance, between the average quality of British and the average quality of Russian coal, so of what value is a comparison of the cost prices of each at the pit-head? There may be, perhaps some advantage and interest in comparing the first costs of British and American coal, but not much practical benefit in the comparison without consideration of the relative positions of the several coal fields to the consuming centres and seaports.

In *The Nineteenth Century* for July, 1898, the present writer estimated, on carefully collected data, the coal crop of the world for 1897 at 574,532,000 tons. From what is now known of the actual output in the principal countries he would place the world's crop in 1899 at not less than 660,000,000 tons. Yet with this enormous addition to the supply there has been something very like a coal famine in Europe,—at all events, prices have been for many months at "famine" rates, and beyond anything ever known since the inflated period of the early seventies. There has been a good deal of crude and curious speculation as to the reason of this. Some people have attributed it to the South African War, but though this has taken a large number of steamers away from their ordinary occupations, it has not increased the consumption of coal. These steamers would have had to fill their bunkers with the same quantities wherever they were employed. It is true that the war has caused the suspension of operations in many of the South African collieries; but the entire annual output of South Africa has never exceeded 2,000,000 tons, while during the war the consumption in South Africa has been curtailed by the suspension of the railways and industrial operations. The war has, to a certain extent, diverted the export movements of coal, but has not increased the total consumption, nor reduced the production to any extent sufficient to have any material effect on the general situation.

For explanation we must look to the

phenomenal industrial expansion and activity of the past two years. Nothing like it has been seen in the history of the world, but being in the midst of it, and each and all of us engaged in our own affairs, we have missed the significance of it. Just think how in every country in Europe, as in the United States, every loom has been whirring, every factory has been smoking, every shipyard and engine-shop has been resounding with the din of industry without cessation during the past two years. The increase in the production of coal has been great, but the increase in the consumption has been greater. That is the simple explanation of the scarcity and of the consequently high prices.

TABLE I.—COAL OUTPUT IN THE UNITED KINGDOM IN 1899

District	Tons
1. East of Scotland	17,749,504
2. West of Scotland	13,393,108
3. Newcastle, Cumberland, North Durham and Northumberland	23,753,161
4. South Durham and North Yorkshire	24,405,784
5. Rest of Yorkshire and Lincolnshire	26,901,495
6. N. and E. Lancashire, Ireland, Kent, etc.	11,159,178
7. West Lancashire and North Wales	16,548,386
8. Midland Counties	27,580,782
9. North Staffordshire, Shropshire and Cheshire	6,799,237
10. South Staffordshire and Worcestershire, etc.	9,412,584
11. Monmouthshire, Somerset, Wilts, part of Brecon and Glamorganshire, etc.	13,753,317
12. South Wales	28,628,767
Total	220,085,303

The United Kingdom and the United States alone amongst coal producers were able to send more last year to other countries. This is a feature in the situation that has, perhaps, escaped general notice. Of the thirty odd coal-producing countries in the world only two, the United Kingdom and the United States, have been able to increase their exports to any material extent. Germany, France, Belgium, Austria-Hungary, and Russia are exporters as well as importers of coal; but last year all of them had to increase their imports and reduce their exports, although all increased their outputs. The United Kingdom is the only industrial country in the world that does not import coal in the ordinary course of trade, for an odd cargo by way of experiment does not count. The United States is now the largest producer in the world, yet also is it a considerable importer of Canadian coal into the North Atlantic ports, and of British, Japanese, and Australian coal into the Pacific ports, because these ports happen to be, to all intents and purposes, nearer to the foreign than to the domestic sources of supply.

We look, first, at the position as regards British coal. Table I. shows, by inspection districts, the output of coal in the United Kingdom in 1899.

The corresponding total in 1898 was 202,042,243 tons, and in 1897 it was 202,199,190 tons. The increase last year over the preceding year was due, to a very large extent, to the resumption of work in South Wales after the strike of 1898. Thus, taking the districts affected by that strike, we have the following figures:—

	1898 Tons	1899 Tons
Monmouthshire, etc.	9,441,658	13,753,317
South Wales generally	19,860,536	28,628,767
	29,302,194	42,382,084

The region of the great strike of 1898 provided 13,079,890 tons of the 18,046,060 tons of the increase in 1899 over 1898. But for the strike of 1898, therefore, so large a development last year would not have been apparent. Table II. shows the growth in output, export, and home consumption during the past ten years:—

TABLE II.—COAL OUTPUT, EXPORT AND HOME CONSUMPTION IN THE UNITED KINGDOM DURING THE PAST TEN YEARS

Year	Output	Exports, including Bunkers and Coke, etc.	Consumed in U. K. for all Purposes
	Tons	Tons	Tons
1890	181,614,288	38.660,272	142,954,016
1891	185,479,126	40,120,861	145,358,265
1892	181,786,871	39.380,756	142 406,115
1893	164,325.795	37,488.070	126 837,725
1894	188.277,525	42,687 430	145.590.095
1895	189.661,362	42,907,302	146,754.060
1896	195,361,260	44 586 811	150.774.449
1897	202,129,931	48 128,464	154,001,467
1898	202,054.516	48,262 699	153.787,817
1899	220,085,303	55,335,369	164,749,934

The Board of Trade monthly returns include coke and patent fuel among the coal exports. Excluding these, the following were the actual British deliveries of coal to other countries in the three years:—

1897	35,354,296 tons.
1898	35.058.430 "
1899	41,180,300 "

Against a decrease of 295,868 tons in 1898, as compared with 1897, there was

an increase of 6,121,870 tons in 1899, as compared with 1898. The increase in the quantity of "bunkers" supplied last year was 962,597 tons. Table III. shows the distribution according to the Board of Trade figures.

Thus we see that while the quantity sent away in 1898, the year of the great Welsh strike, was practically the same as in 1897 (though the sales to foreign

TABLE III.—COAL EXPORTS OF UNITED KINGDOM, 1897-1899

To	1897 Tons	1898 Tons	1899 Tons
Russia	2,015,525	2,195.067	3,397,791
Sweden and Norway	3,460,974	3,612.445	4,493,586
Denmark	1,879,182	2,045,768	2,051.423
Germany	5,042.781	4.711,370	5,059.661
Holland	947,235	931,134	1,277 792
France	5,697.292	5,710,113	6,863,887
Portugal, Madeira	683.002	741,623	755 365
Spain and Canaries	2.257,306	1,789,866	2.292 395
Italy	4,834,054	4,665,166	5,513.452
Turkey	554,355	510,683	490.688
Egypt	1,860,723	1,907,505	2,125 921
Brazil	1,046 075	1,010.109	967,778
Gibraltar	332,806	399,605	325,837
Malta	454,784	462,143	419,461
East Indies	589,016	658,716	863,177
Other countries	5,441,808	5,211,483	6,210.349
Total exports	37,096 918	36.562,796	43,108,568
Supplied for use of steamers in foreign trade	10,455,758	11,264,204	12,226,801
Total sent out of country	47,552,676	47,827,000	55,335,369

countries were smaller), there was an increase in 1899 of nearly eight million tons over both years. The increase in the declared value of the exports is more remarkable. Thus:—

In 1897 the value of coal exported was	£16,654,955
In 1898 " " "	18,135,502
In 1899 " " "	23,105,691

These figures express only the value of the coal sold to foreigners, and do not include the value of coal supplied as "bunkers" to foreign-going steamers.

Varying and revising the returns as published monthly by the Board of Trade, we have in Table IV. a summary of the exports from Great Britain to the various groups of markets.

It is interesting to note the quantities exported from the several producing centres. These are given in Table V.

The German production of coal in 1899, though not so large as it might have been but for the labour troubles and interruptions, was larger than was generally expected. Thus, the collieries of the German Empire and Luxemburg turned out, in comparison with 1898:—

	1898. Tons.	1899. Tons.
Coal	96,309,652	101,621,866
Brown coal, or lignite	31,648 898	34,202,561

Germany is the third largest coal producer in the world. The production of lignite must be kept in view, because, though it does not directly enter into the international competition, it is used on the German railways, which, but for it, would have to burn imported coal.

The Royal Commission of 1871 had not the dimmest preconception of the enormous coal development of the United States, which has become the largest producer in the world; and not only the largest, but, with the exception of India, the cheapest in respect of first cost at the pit-heads. The American supply seems destined to control the future situation in the Atlantic region, as the China supply is, in the writer's opinion, destined to control the ultimate situation in the Pacific region. The figures relating to the United States output of coal, given in Table VI., are a revelation to the complacent Briton.

TABLE IV.—CLASSIFIED COAL EXPORTS FROM GREAT BRITAIN

Shipped to—	1898 Tons	1899 Tons
1. Germany, Scandinavia, North Russia, Holland, Belgium	13,501,198	16,394,518
2. France, Spain, Portugal, Mediterranean generally, Levant, Danube and South Russia	16,841,411	19,537,685
3. West Africa	379,488	488,486
4. South Africa	258,150	496,148
5. East Africa, Mauritius, Aden, etc	289.262	291,801
6. Indian Peninsula	330,908	432,890
7. The Straits and the Far East	585,203	601,530
8. Atlantic ports of North and Central America and West Indies	405,486	248,403
9. Atlantic ports of South America	2,109,828	2,263,193
10. Pacific ports of North and South America	357,496	425,643
Totals	35,058,430	41,180,300

TABLE V.—COAL EXPORTS FROM GREAT BRITAIN'S PRODUCING CENTRES

	1898 Tons	1899 Tons
Welsh and Monmouthshire coal shipped from the Bristol Channel ports	12,087,771	18,606,005
Lancashire coal shipped from the northwest ports	987,378	579,387
Durham and Northumbrian coal shipped from the northeast ports	11,959,540	12,307,651
Midland coal shipped from the Humber ports	3,394,730	3,637,890
Odd lots from minor ports	204,032	266,517
Fife and other coal shipped from East of Scotland ports	4,709,185	4,563,295
Lanarkshire and Ayrshire coal shipped from West of Scotland ports	1,714,834	1,213,769
All other ports	960	5,786
Totals United Kingdom	35,058,430	41,180,300

TABLE VI.—OUTPUT OF COAL IN UNITED STATES*

States.	1899 Short Tons	1898 Short Tons
Alabama	6,535,283	7,234,558
Arkansas	1,205,479	911,342
California and Alaska	160,288	160,335
Georgia and North Carolina	255,662	260,008
Colorado	4,076,347	5,425,618
Idaho	1,139	20
Illinois	18,599,299	23,434,445
Indiana	4,920 743	6,529,826
Indian Territory	1,381 460	1,677,100
Iowa	4,618 842	5,265,480
Kansas	3,406 555	3,948,197
Kentucky	3,887,908	5,120,370
Maryland	4 674,884	5,516,363
Michigan	315,722	523,084
Missouri	2,688,321	3,833,546
Montana	1,479.803	1,956.300
New Mexico	992 288	1,200 668
North Dakota	83,895	116,929
Ohio	14,516,867	16,679,880
Oregon	58,184	90 302
Pennsylvania	65,165.133	75,591,554
Tennessee	3,022,896	3,361.465
Texas	686.734	938.765
Utah	593,709	787,258
Virginia	1,815,274	2,332,627
Washington	1,884.571	2,020,260
West Virginia	16.700,999	18,755,222
Wyoming	2,863,812	4,547,733
Total bituminous	166,592.023	198,219.255
Pennsylvania anthracite	53,382,644	60,320.395
Grand total, short tons	219,974,667	258 539 650
Equal to long tons	196,405,935	230,838,973

* These figures are those of the U. S. Geological Survey. They do not agree with those of the British Board of Trade, which make the U. S. output in 1899 218.376,000 tons. The correct total probably lies between the two.

The increase here shown of nearly 34,500,000 tons (about as much as the entire output of South Wales) in 1899 over 1898, followed upon one of 20,000,000 tons in 1898 over 1897. In two years the United States have, if these figures be accepted, added 54,500,000 tons to their previously large contributions to the world's supply of coal. No one foresaw this,—no one could possibly have foreseen it. By many it was thought that in a few years' time the American output would exceed the British, but no one expected it so soon, and no one can place a limit on the American production of the next five years.

It is not the industrial activity in Britain alone that has caused the run on coal. Great Britain is the only country in the world which produces more coal than it consumes, and has a surplus for export without importing. The United States, Germany, France, and Belgium are all exporters of coal, as has been said; but they are also extensive importers. Canada, South Africa, and British India are in the same category. The United Kingdom, and New South Wales, and Japan alone have surplus coal to export without any need to import, though imports are not unknown to these last-named. It has been the great need of the European countries that has caused the coal famine from which we are now suffering. The consumption in France has been, and is, so great that it is estimated that the home supply will this year be 12,000,000 tons short of the country's requirements. That quantity will have to be imported.

In the first four months of this year France took from Great Britain upwards of a million tons more than in the corresponding portion of last year, and also began to derive supplies from America. The long strike in Austria caused exceptional demands there for German, British, and American coal; and in Russia there has been the pinch of extreme need for foreign coal owing to the great increase in industrial consumption. In the first four months of this year Great Britain sent to Russia 1,200,000 tons more than in the corresponding portion of last year, and that was before the Baltic shipping season had opened. On the coal crisis in Russia, Mr. H. Cooke, in a consular report to the British Foreign Office, says:—

"While the undoubted rise and development of late years in the industrial activity of Russia, and the extension of railways and navigation, have been, perhaps, the main causes, they are by no means the only explanation of the present scarcity and high prices of coal. The coal-mining industries themselves are not sufficiently developed to meet the demand, in spite of an increasing output, and in spite of a protective tariff, while insufficient railway accommodation, difficulties of delivery, and generally defective transport arrangements, play an important part in the situation. Another important consideration is the dearness of naphtha and kindred fuels preceding the rise in coal prices. The activity of syndicates and rings, by limiting production and bringing up prices, and the universal speculation and gambling attending of late

the coal and other industries of Russia, are equally important factors against which the government has taken summary administrative measures,—at least as regards coal. * * * * Other subsidiary causes, said more or less to have influenced the situation, have been the want of hands, rise in wages, decrease of hours, and superabundance of national and religious holidays,—to an extent, however, which has been much disputed."

The extent to which both coal-mining and manufacturing have developed in late years in Russia seems not to be generally known. But an idea may be got from the following comparative statement of the quantities of coal produced in, and imported into, the Russian Empire:—

Year.	Coal Produced Poods	Coal Imported Poods
1877	110,060,000	95,000,000
1887	277,000,000	100,000,000
1898	746,000,000	196,000,000

Taking the ton as equal to sixty-two poods, it will be seen that the Russian output has in twenty years increased from 1,774,193 tons to 12,032,258 tons, and that the imports in the same time increased from 1,532,258 tons to 3,161,290 tons. This year (1900) the output of the Russian mines has been so far short of the national requirements that the customs duties have had to be relaxed to admit of a larger import. The deposits of the Russian coal fields, however, have as yet barely been touched. The Donetz coal field alone is said to hold 13,875,000,000 tons,—enough to last for 800 years, with progressive increase of consumption, though the coal is not of the first quality. There are other fields hardly less extensive, and, altogether, there is a practically inexhaustible supply of (low quality) coal in Russia as yet undeveloped.

One of the subjects pressing for consideration, which might have come within the scope of inquiry of another British Royal Commission, is that of the supply of steam coal to foreigners, competing with British shipowners and traders, and possessing fleets which may be employed against the power of the British Empire whilst burning Welsh coal. It is beyond doubt that Welsh steam coal is the best coal in Europe for naval purposes,—whatever may be the case in America,—and it seems in the highest degree absurd that the depletion of the Welsh coal fields should be hastened in order to fill the bunkers of hostile warships. There is good reason to suspect that some of the recent great export pressure has been due to the requirements of certain foreign navies, though the purchases were ostensibly for railway purposes. It is not usual for railway companies to burn the best Cardiff steam coal at a price higher than any other coal in the world; and it is a fair subject for discussion whether the British Government should not "commandeer" all the Welsh steam coal, other than is required to fill the bunkers of outward-going steamers and to keep up the supplies at coaling-stations under the British flag.

The last British Royal Commission appointed to inquire into the whole subject of the coal supply reported in 1871. The reasons why another inquiry is deemed desirable,—though the government has declined to nominate another Commission,—may be briefly stated. In 1871 the Royal Commission estimated that the population of the United Kingdom in 1901 would be 35,000,000; the census returns will probably show 41,000,000. They estimated that in 1901 the consumption and exports of British coal would require an output of 174,400,000 tons; the output in 1899 was 220,000,000 tons. They assumed that the exports would not exceed 12,000,000 tons; the sales last year to foreigners exceeded 43,000,000 tons. It is probable that the output in 1901 may be 225,000,000 tons, or over 50,000,000 tons more than the estimate of the Royal Commission.

Such an enormous difference calls for reconsideration of all the estimates relating to the probable duration of the coal fields. The British exports are already three and a half times more than the Royal Commission thought they would ever be, and yet the development which they looked for has taken place in other countries, though not as yet to

any material extent in China. The estimates dealt with by the Royal Commission were those of Professor Stanley Jevons, who computed the probable duration of the coal fields at 110 years; of Mr. Price Williams, who computed it at 360 years; and of some of their own number, who computed it at 276 years.

The duration of the Scotch output was computed then as likely to be 820 years, on the assumption that the annual output would not exceed 12,000,000 tons. But the Scotch annual output is now three times that, and this branch of the subject may be dwelt on a little because in Scotland there have been the most recent inquiries by experts into the supplies.

Scotland, now one of the leading producing areas of the United Kingdom, has developed its output enormously of late years. Some people think that it has developed too fast and too far, and that the Scotch coal fields are being too rapidly worked out. Mr. R. W. Dron, for one, is of that opinion, and he laid some thought-provoking facts and figures recently before the Mining Institute of Scotland. According to Mr. Dron, the Lanarkshire coal field cannot continue its present output for more than forty years, and the whole of the cheaply-worked coal in Scotland will be worked out by the close of the twentieth century,—which, of course, unlike the German Emperor, we do not believe has yet begun.

The method of inquiry pursued is interesting. A seam of coal twelve inches thick and one square mile in area should contain rather more than 900,000 tons, if there were no faults and barriers; but allowing for these and for coal lost in working, the estimate is 600,000 tons per foot thick per square mile. In Scotland, seams known to be workable are classed as "proven," and seams of less than 2 feet thickness and all coal-seams of the limestone measures lying below the upper coal measures are classed as "unproven." In order to ascertain what has been already taken out of the seams, the output of the whole United Kingdom since coal-mining began in 1400 has been summed up and the Scotch proportion taken as, on the average, 13.3 per cent. On this basis the amount of coal which has been mined in Scotland up to last year was 1,504,000,000 tons. Apportioning this amongst the several Scottish counties, Table VII. has been compiled to show the extent and distribution of the total quantity of available coal in Scotland.

It is regarded as certain that the coal-seams of the counties of Fife and Midlothian are continuous under the waters of the Firth of Forth. The width across is about fourteen miles, and the water is nowhere deeper than 100 feet. Mr. Dron estimates for working the coal for a distance of only three miles from each shore, and on this basis, plus allowances for barriers, etc., arrives at 1,000,000,000 tons as a reasonable estimate of the coal lying in reserve under the estuary of the Forth. But there is no reason why the working should be limited to three miles, and there are islands in mid-channel on which pits can be sunk, such a project being by no means novel. The last Royal Commission reported that there were 1,800,000,000 tons of recoverable coal under the Forth. It has not yet been touched, so the quantity is probably there still. On Mr. Dron's estimates, however, the following is the net position in Scotland:—

	Tons
"Proven" coal at moderate depths	4,634,785,600
"Unproven" coal at great depths	5,897,007,120
Total unworked coal	10,531,792,720

Supposing this estimate to be correct, how long will the quantity last? For nearly four centuries the output and consumption have been steadily progressive, so that we have to figure upon not merely the quantities now reached, but upon progressive increase of these quantities in the future. The Royal Commission estimated the probable consumption of the United Kingdom in each decade after 1871, proceeding on a geometrical increase of population and a probable decrease in consumption per capita. Thus, they worked out a prospective home consumption in 1891 of 146,300,000 tons, and the actual total

TABLE VII.—THE AVAILABLE COAL SUPPLY IN SCOTLAND

County	Total "Proven" Coal Tons	Quantity Worked Tons	Quantity Still to Work Tons	Quantity of "Unproven" Coal in Reserve (Estimate) Tons
Argyll, Dumfries, Perth and Sutherland	117,788,000	12,788,000	105,000,000	166,843,120
Ayr	1,355,316,000	215,824,000	1,139,592,000	1,066,652,000
Dumbarton	64,992,000	21,056,000	43,936,000	48,714,000
Lanark	1,900,542,000	840,736,000	1,059,806,000	885,324,000
Renfrew	84,036,000	5,264,000	78,772,000	87,184,000
Stirling	256,422,000	90,992,000	165,430,000	349,020,000
Clackmanan	83,097,000	21,056,000	62,041,000	151,950,000
Midlothian	702,519,600	56,400,000	646,119,600	1,019,122,000
Fife and Kinross	1,227,714,000	179,728,000	1,047,986,000	966,624,000
Haddington	135,660,000	18,048,000	117,612,000	57,988,000
Linlithgow	210,003,000	42,112,000	168,491,000	197,586,000
Firth of Forth (submarine)	----------	----------	----------	1,000,000,000

was 145,358,265 tons. This was not a bad estimate twenty years ahead, but the 1891 total worked out at 3.846 tons per head of the population instead of 4.578 anticipated by the Royal Commission, the population by the census being 37,797,073 instead of 31,955,000 in their estimate. This is indicative of a greater economy, or the larger use of substitutes, than was expected.

On the other hand, the exports have far exceeded their expectations. The Royal Commissioners saw reason to doubt whether the exports would increase, and thought they would remain stationary at about 12,000,000 tons per annum. As a matter of fact, the exports last year (1899) were 43,108,568 tons, and the quantities supplied to the bunkers of foreign-going steamers were 12,226,801 tons,—in all 55,335,369 tons. Here, then, was a woeful miscalculation. Taking, however, the Royal Commission estimates of future consumption, which have come out so far fairly well, the "proven" coal of Scotland will be exhausted by the year 1994, and all the "unproven," or reserve, coal by the year 2086. Mr. Dron says:—

"It is, of course, evident that long before these dates are reached the continued increase of the output will have received a check; and that, just as the output has gradually increased, so now will it gradually diminish. The vital consideration is that within a comparatively short time the mines of Scotland will be unable to supply the necessary coal for the continuance of that increase of trade and population of the country which has been so marked a feature of the present century. Assuming that the annual increment continues until 1941, when the Scottish output will have reached a total of 40,000,000 tons per annum, there will be sufficient coal to maintain the output at that rate until the year 2160; but even on this assumption, cheaply-worked coal will last only until about the end of the next century."

It seems to the present writer, however, that sufficient account is not taken of the probable development of mining dexterity. The term "cheaply-worked," applied to coal, is only a relative one, and future generations will be able to unearth the deepest seams at a cost which to us is impossible. This should be kept in view as a qualification of the alarmist calculations of the president of the London (1899) Conference of Mining Engineers, who advanced reasons for thinking that all the best seams of coal in the United Kingdom will be exhausted within the next fifty years.

In Scotland, Mr. R. T. Moore recently computed that all the workable coal in Lanarkshire (which supplies at present 55.9 per cent. of the whole output of Scotland) will be depleted in twenty years. Mr. Dron, whom we have already quoted, says it would be exhausted in forty years, "if it were possible for Lanarkshire to continue producing coal at the rate of 55.9 per cent. of the output of Scotland." But it is not possible, or probable, and this is just one of the many "ifs" that qualify the various estimates and prophecies about the future of the coal supply. It is not possible, because Ayrshire, with 24½ per cent. of the unworked "proven" coal in Scotland, as yet has produced only 14.35 per cent. of the

annual output; and Midlothian, with 13½ per cent. of the "proven" coal, as yet has produced only 3.75 per cent. of the annual output. It is not safe to calculate the endurance of any coal field from the present percentage contribution of that field to the present total output.

Another qualification of estimates of the duration of coal supplies may be suggested. These estimates are based on the known waste or loss in working under present methods. That loss in some districts is as high as 25 and 30 per cent., but in others it is as low as 2 per cent. There seems no good reason why, with good and careful mining, the loss should not be reduced to the minimum, and the available supply increased. It is monstrous to think that in these days of dear coal and prospective exhaustion in many collieries the small coal is deliberately left in the workings, simply for want of washing-plant equipment.

The futures of the coal supply and the gas supply are, of course, inseparable. Broadly speaking, gas-coal in Great Britain rose last year about 25 per cent., and the contracts for the 1900-1901 gas season will be at fully 50 per cent. higher prices than those of the past season. This means an enormous addition to the national gas bill, unless gas managers can recoup the extra cost, or some of it, by economies in working. Happily, by the new system of retorts there is a large saving in fuel, otherwise gas would be at a price within reach of only the very well-to-do. There seems to be about as much wastefulness in the distribution of the gas supply as there is in the mining of coal, for in both something like 10 per cent. is lost, without benefit to anybody. By a saving of the great leakage between the gasometer and the consumer's burner the net cost of gas could be materially reduced. Then there is another thing to be considered in this branch of coal consumption. The greater portion of the increase nowadays in the consumption of gas is not for illuminating, but for machinery and cooking purposes. Therefore a lower quality of gas should suffice, and even for illuminating purposes high candle-power is not required owing to Welsbach and other improved modern burners.

The dearer gas becomes through dear coal, the greater must be the impetus given to electric lighting. Great Britain has been behind other countries in adopting the electric light, mainly because she has had cheaper coal, and, therefore, cheaper gas, than any other country in the world. The more general adoption of the electric light in Great Britain will tend to a reduced consumption of coal. And there is room for tremendous extension, as there are now only about 7,000,000 incandescent lamps in London and the provinces, and only about 150 towns which have a public supply of electricity. Dear coal affords a splendid chance for the electrician, and the more extensive use of electricity for illuminating purposes will be one of the things to help make coal cheaper again. Gas managers are amongst those who propose a heavy export tax upon coal, but would not such an impost have just the effect of keeping up the price in the home trade?

Another effect of dear coal is to direct increased attention to liquid fuel for steam-raising purposes. Liquid fuel is already in larger use by steamers, especially in the Eastern trade, than is generally known. Hitherto one obstacle in the way of the use of oil-fuel has been the difficulty of obtaining supplies on the voyage, but now regular storage has been, or is being, provided at Singapore, Penang, Hong-Kong, Kobé, Yokohama, Bombay, Colombo, Suez, and other coaling stations. The prejudice against the storage of this fuel aboard ship is disappearing, and Lloyds have laid down certain rules and precautions on the subject which are easily observed; and as the oil-fuel occupies much less space than coal, its use leaves bunker space available for freight-paying cargo.

One of the objections to the use of liquid fuel, relating to the waste of steam and water in spraying, is being overcome by the employment of more evaporators, and by other devices. Quite

recently Sir W. G. Armstrong, Whitworth & Co., Ltd., constructed in their yard at Walker-on-Tyne two steamers for the Shell Transport Line, for the conveyance of bulk oil, and the consumption of oil-fuel on a new principle. This consists in the employment of hot air in spraying the oil and promoting economical combustion. This system has been fitted up on board the *Cardium* alongside the steam-sprayer system, and careful notes are to be made of the results in each case for comparison. It is said that the experience of some of the steamers in the Eastern trade is that the steaming capacity of a boiler is increased 50 per cent. by the use of liquid fuel under forced draught, over coal with natural draught.

In connection with this, the following remarks from a speech by Sir Marcus Samuel at the launch of the *Cardium*, above referred to, are of interest:—"A notable feature of liquid fuel is that it occupies much less space and does double the work of coal. There are German boats using liquid fuel on the Yangtse River, in China. There is also the fact that the Hamburg-American Line are actually adopting it, that the Rotterdam Lloyd Line have decided to adopt it, and that the P. & O. Company are considering it. * * * * He much regretted the attitude of the engineers of the Royal Navy in regard to the question. * * * * The German Government are adopting it for their navy; Emperor William has adopted it for the *Hohenzollern;* and it is extremely unsatisfactory to find that our own naval experts are unable to deal with the question, which is very simple, but of overwhelming importance. * * * * The complete combustion of liquid fuel is far more smokeless than that of any coal even of the very best kind. * * * * On a small torpedo-boat even a shovelful of coal put on means a difference in the speed, and it stands to reason that a system under which one can burn unlimited quantities of fuel automatically and irrespective of the heat in the stoke-hole (where no stoker need be) is preferable."

Not only preferable, but imperative, one would think, if oil-fuel can do all that is claimed for it. But even if short of absolute perfection, this fuel has the merit of being both a cheaper steam-raiser and of occupying less storage space than coal. And now when after the enormously increased cost of construction steamship owners have to face the enormous increase in the cost of bunker coal, they must perforce turn their attention to other fuel. The extensive use of liquid fuel will be another influence in making coal cheaper again.

It is not to the stoppage, or arbitrary restriction, of exports that the British consumer must look for relief in his coal bill and for preservation from exhaustion of the national supplies. The stoppage of the export of coal would mean the ruin of the industries and commerce of the British Isles. There is no other heavy cargo to give the vessels which steam outwards to all parts of the earth in search of cheap food-stuffs for the hungry people and of material for their insatiable mills and factories. But where relief may be found is in the use of liquid fuel, the diminished consumption of coal-gas, greater economy in mining, and the prevention of waste at the workings. Further relief will be found by the greater economy in the use of coal in every branch of consumption, which, in many factories and most households, is very wasteful; and still further by the utilisation of the unmeasured millions of horse-power latent in running streams. Millions of tons of coal per annum could be saved by the effective use of water-power now running to waste.

The plain fact to be deduced from a consideration of the whole situation is that the coal supply of Europe at large was, last year, short of the requirements of industrial Europe and dependent markets. Hence, the great advance in prices, at a time, too, of dear freights caused by the absorption of tonnage in connection with the Transvaal war, and by the general activity of trade all over the world. Prices having been, by the comparative scarcity and peculiar conditions, sent up to a level which renders industries unremunerative, will be brought down again by the consequent

curtailment of consumption. It is the natural effect of high prices to check consumption, and so the bane carries its own antidote. A good deal of mischief may be done, however, before coal prices return to a reasonable level, and undoubtedly the coal famine in Europe has given America an opening for both coal and iron that she is not likely to allow to be closed again.

The projection of American coal into the international arena is indeed the great economic feature of the time. It is not probable that American coal will go to feed British factories, but if it goes to feed some of the foreign factories and coaling stations hitherto accustomed to be fed from South Wales and the north of England, it will save the drain on the British fields for foreign uses. Thus the British exports will be abated, or at all events not increased, and they are now as large as they need be.

While it is for a Royal Commission, or a committee of experts, to determine what are the present coal resources of the British Isles, ordinary persons may take certain facts and probabilities into consideration. One is that the British Empire now produces about five-twelfths of the world's coal, and that only the fringe of the resources of India, Africa, and Australasia has as yet been touched. Another is that the industrial consumption of coal will not increase in the same rate in the future as in the past because science is teaching us both how to economise coal and how to develop the employment of electric energy. For the present, however, the coal question is undoubtedly a most anxious one for all engaged in industrial pursuits.

THE SLOOP-OF-WAR "WAMPANOAG"

A ONCE FAMOUS, BUT LONG-FORGOTTEN, UNITED STATES CRUISER

By Chief Engineer B. F. Isherwood, U. S. Navy

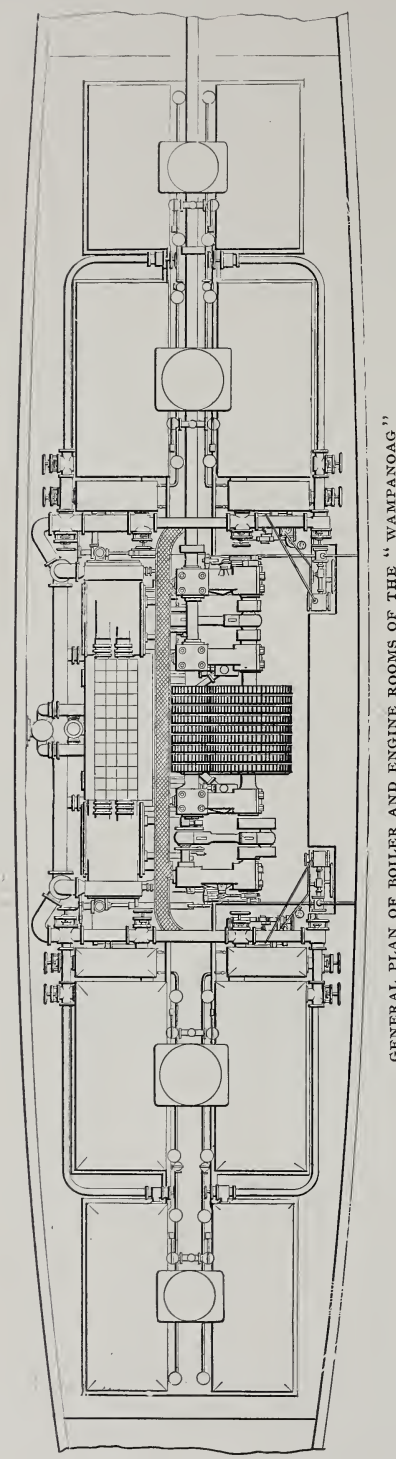
Continued from the August Number, which contained an Account of the Conditions that led to the Building of the "Wampanoag" and the Several Vessels of her Class

THE dimensions and proportions of the hull of the *Wampanoag* are given in the table on page 405. There were two geared engines, each having one simple cylinder of 100 inches diameter and 4 feet stroke of piston not steam jacketed. They revolved one fixed screw—that is to say, the screw could not be lifted out of water, and it made 2.05 revolutions for each double- stroke of the pistons.

The two cylinders were horizontal, and they acted directly upon the crankshaft. They were placed on the starboard side of the vessel, and had the surface condenser, the air pumps, the circulating pumps, and the channel ways and reservoirs of these pumps between them. The crankshaft carrying the large cog-wheel was on the port side of the vessel, and this wheel was opposite the condenser and pumps. The corresponding pinion on the screw shaft was between the crankshaft cog-wheel and the condenser. The connecting rod of the after engine worked beneath the screw shaft. Each engine had its own air pump and circulating pump, but the condenser was common to both engines. The valve chest of each cylinder was upon its outer side—that is to say, on the forward side of the forward cylinder, and on the after side of the after cylinder.

The main steam valves were double-ported equilibrium slides, working on their edges against a vertical seat. Each was operated directly from the crankshaft by means of two eccentrics and a Stephenson link, and, when in full gear, cut off the steam by lap at two-thirds of the stroke of the piston, leaving the remaining one-third to be performed by the expansion of the steam. There was no separate or independent expansion valve, but the measure of expansion with which the steam was used could be momentarily varied between two-thirds and three-tenths of the stroke of the piston by simply turning a wheel. A small steam cylinder was attached to the link gear, and a single person, with its aid, could start, stop, and reverse the engines, or change the point of cutting off the steam, with great rapidity. The pumps were horizontal and double-acting; they had a shorter stroke of piston than the steam piston, and were worked by a rock shaft which received its movement from the main crosshead. The surface condenser, common to both engines, was placed immediately above the pumps.

The engines were very compactly arranged, with no waste spaces, and would loosely fill a parallelopipedon. All the important parts requiring continual supervision and adjustment were unusually accessible, particularly the main journals and the crank pin journals, the steam valves and their gear, the main crossheads, the steam pistons, and the pistons and valves of the pumps. Every part was uncovered and immediately



GENERAL PLAN OF BOILER AND ENGINE ROOMS OF THE "WAMPANOAG"

beneath the eye of the engineer, and was specially designed with a view to facility and economy of repairs.

The purpose of the gearing was to reduce the number of reciprocations made per minute by the moving parts of the engine, in order to prevent the excessive vibrations set up in the hull by the unbalanced *vis viva* of these parts, which vibrations, for equal stroke of piston, are in the ratio of the square of the reciprocations per unit of time into the weight of the moving parts. Had equivalent ungeared engines been employed, other things than the diameter of the cylinders being equal, the vibration-producing cause would have been about doubled. In other words, the vibrations are reduced in the ratio of the gearing. All simple engines developing large power, placed in wooden vessels to be driven at high speed, had failed by reason of the enormous vibration produced in the hulls. Such vibration would have defeated the purpose of the *Wampanoag*.

The purpose of the gearing was perfectly accomplished; the working of the engines was extremely smooth, and even at the highest speeds there was no sensible vibration of the hull, notwithstanding its wooden material and its considerable length in proportion to breadth and depth. Of course, the employment of gearing increased the weight of the engines and of the space occupied by them. The gearing acted as a fly-wheel to the engines, and not only caused them to run more smoothly, but enabled all the main and crank pin journals to be operated with slacker keying, thereby diminishing their friction and their tendency to heat.

The engines were fitted with a clutch coupling in the screw shaft, whereby they could be disconnected from the screw almost instantly, so that the screw could be revolved by the reaction of the water upon it when the vessel was under sail alone. By the aid of the gearing as a fly-wheel, the engines could be worked smoothly when uncoupled from the screw. A considerable number of indicator diagrams taken simultaneously from both cylinders under this condition

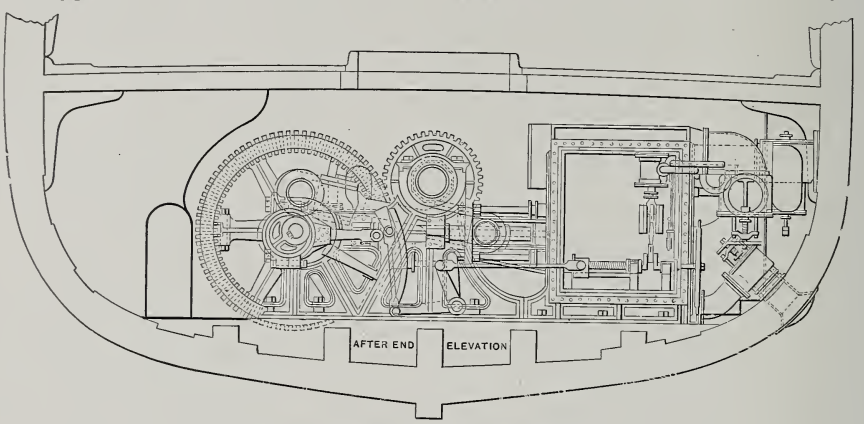
DIMENSIONS AND PROPORTIONS OF THE "WAMPANOAG."

Length in feet on mean load line from forward edge of rabbet of stem to after edge of forward sternpost	335.50
Extreme breadth in feet on mean load line	45.16
Depth in feet from mean load line to lower edge of rabbet of keel	18.00
Distance in feet of the greatest immersed transverse section abaft the middle of the length of the mean load line	10.25
Height in feet of the lowest port sill at the greatest immersed transverse section above the mean load line	9.25
Depth in feet of keel and false keel below the lower edge of the rabbet of the keel — Forward,	1.833
Mean,	2.312
Aft,	2.792
Displacement in cubic feet of the hull (body only) to mean draught of water 10.23 feet above lower edge of rabbet of keel	68414.9
Centre of displacement before the greatest immersed transverse section, in feet	6.96
Centre of displacement below the 10.23 feet draught of water above lower edge of rabbet of keel, in feet	4.05
Area in square feet of horizontal section of hull at the 10.23 feet draught of water above lower edge of rabbet of keel	9766.0
Centre of gravity of the area of horizontal section of hull at the 10.23 feet draught of water above lower edge of rabbet of keel, before the greatest immersed transverse section of the hull, in feet	5.12
Difference of draught of water of the horizontal section of the hull at the mean draught 10.23 feet above lower edge of rabbet of keel, in feet	1.50
Displacement in tons per inch of draught at the 10.23 feet mean draught of water above lower edge of rabbet of keel	23.3
Displacement of hull alone, or its weight in tons, including weight of keel and false keel	1987.0
Load displacement in cubic feet to mean load draught of water, including keel and stem	152668.5
Load displacement in tons (sea water 1.026 specific gravity) to mean load draught of water, including keel and stem	4370.5
Displacement in tons per inch of draught at the mean load draught of water	27.38
Load displacement in cubic feet to mean load draught of water, above lower edge of rabbet of keel, body only	151650.4
Position of centre of gravity or buoyancy of body only, abaft the middle of the length at the mean load line, in feet	4.97
Position of center of gravity or buoyancy of body only, abaft the middle of the length of the mean load line, in terms of that length $\frac{1}{67.5}$ or	0.0148
Position of centre of gravity or buoyancy of body only below the mean load line, in feet	7.40
Content in cubic feet of the portion of the displacement before the middle of the length of the mean load line, (body only)	72386.24
Content in cubic feet of the portion of the displacement abaft the middle of the length of the mean load line, (body only)	79264.16
Excess in cubic feet of the posterior portion	6877.92
Ratio of excess to the whole displacement $\frac{1}{22}$ or	0.0455
Content in cubic feet of the portion of the displacement before the centre of buoyancy	75837.4
Content in cubic feet of the portion of the displacement abaft the center of buoyancy	75813.0
Excess in cubic feet of the anterior portion	24.4
Ratio of excess to the whole displacement	0.000161
Centre of gravity of anterior portion before the center of displacement, in feet	60.01
Centre of gravity of anterior portion below the mean load line, in feet	7.45
Centre of gravity of posterior portion abaft the centre of the whole displacement, in feet	60.03
Centre of gravity of posterior portion below the mean load line, in feet	7.315
Ratio of displacement to its circumscribing parallelopipedon	0.55607
Area in square feet of the greatest immersed transverse section, exclusive of keel	694.4
Centre of gravity of the greatest immersed transverse section below the mean load line	7.97
Ratio of the greatest immersed transverse section to its circumscribing parallelogram	0.85425
Area in square feet of the horizontal section through the mean load line	11478.42
Centre of gravity of the horizontal section through the mean load line, abaft the middle of the length, in feet	7.02
Ratio of the horizontal section through the mean load line to its circumscribing parallelogram	0.7576
Area in square feet of the anterior portion of the horizontal section through the mean load line forward of the centre of gravity of that section	5724.32
Centre of gravity of the anterior portion of the horizontal section through the mean load line before the centre of gravity of the whole section, in feet	67.22
Area in square feet of the posterior portion of the horizontal section through the mean load line aft of the centre of gravity of that section.	5754.1
Centre of gravity of the posterior portion of the horizontal section through the mean load line abaft the centre of gravity of the whole section, in feet	66.885
Difference in feet of draught of water to load line (body only)	1.75
Area in square feet of diametrical plane including keel and stem to mean load line	5938.0
Ratio of area of diametrical plane to the area of the greatest immersed transverse section	8.52
Height in feet at latitudinal meta centre above the centre of displacement or buoyancy	10.237
Height in feet of latitudinal meta centre above the mean load line	2.837
Height in feet of longitudinal meta centre above the centre of displacement or buoyancy	469.61
Height in feet of longitudinal meta centre above the mean load line	462.21
Immersed surface in square feet of the hull including the sides and the the bottom of the keel	20023.06
Number of square feet of surface in the plain sails, including staysails	29112.
Number of square feet of sail surface per square foot of greatest immersed transverse section	41.924
Number of square feet of sail surface per ton of displacement	6.645

showed that a pressure of 1.5 pounds per square inch of pistons was required to work the unloaded engines, and that this pressure was sensibly constant at all speeds of piston.

The loss of speed by the vessel under sail alone, due to the resistance of the dragging revolving screw, was about one-seventh; that is to say, if the vessel under sail alone, without impediment from the screw, could make 14 geographical miles per hour, she would make 12 geographical miles per hour with the screw uncoupled, revolving, and dragging. This proportion was

Per cent. which the waste space in clearance and steam passage at one end of each cylinder is of the space displacement of each piston per stroke	6.936
Area of steam port at one end of one cylinder	567 sq. in.
Diameter of the crosshead journal.	15 in.
Length of the crosshead journal	22 in.
Diameter of necks of connecting rods	10 in.
Length of connecting rods between centres of journals	10 ft.
Number of main journals for both engines	4
Diameter of main journals	18 in.
Length of main journals	4 ft.
Diameter of main shaft cog-wheel over cogs	10 ft. 6¼ in.
Number of cogs in periphery of cog-wheel of main shaft	84
Aggregate length of cogs of cog-wheel of main shaft	9 ft.
Diameter over cogs of pinion on screw shaft	5 ft. 3⅛ in.



THE ENGINES OF THE "WAMPANOAG"

obtained from experiments made by the writer on the U. S. steamship *Massachusetts*, the screw of which could be hoisted entirely out of water and the vessel propelled by the sails alone. In the case of the *Wampanoag*, the axial speed of the screw due to the revolutions of the screw by the reaction of the water upon it when uncoupled and dragging with the vessel under sail alone, was five-eighths of the speed of the vessel, the "drag" of the screw amounting to three-eighths of that speed. This proportion was sensibly constant at all speeds of vessel.

Number of cylinders	2
Diameter of cylinders	100 in.
Stroke of pistons	4 ft.
Diameter of piston rods (2 to each cylinder)	7½ in.
Net area of each piston	7809.8023 sq. in.
Space displacement of each piston per stroke	216.939 cu. ft.
Waste space in clearance and steam passage at one end of each cylinder	15.0465 cu. ft.
Number of cogs in periphery of pinion on screw shaft	41
Ratio of the gearing	2.05
Diameter of screw shaft journals	18 in.
Length of screw shaft journals	4 ft.
Diameter of crank-pin journals	16 in.
Length of crank-pin journals	27 in.
Surface condenser, one in common to both engines.	
Number of brass tubes in surface condenser	7.168
Outside diameter of condenser tubes	⅝ in.
Exposed length of condenser tubes	6 ft.
Aggregate area of exposed surface of tubes, calculated for their outside circumference	7,037 sq. ft.
Aggregate cross-section of half the tubes for passage of refrigerating water, calculated for inside diameter of tubes	1,047 sq. in.
Number of water circulating pumps	2
Diameter of circulating pumps	28 in.
Diameter of piston rod of circulating pump	3½ in.
Net area of each circulating pump piston	598.37 sq. in.
Stroke of piston at each circulating pump	2.482 ft.
Space displacement of piston of each circulating pump per stroke	10.314 cu. ft.
Number of air pumps	2
Diameter of air pumps	34 in.
Diameter of piston rod of air pump	4 in.

Net area of each air pump piston	901.64 sq. in.
Stroke of piston of each air pump	2.482 ft.
Space displacement of piston of each air pump per stroke	15.540 cu. ft.
Number of injection valves	2
Diameter of injection valves	15½ in.
Outboard delivery valve, one in common to both engines.	
Diameter of outboard delivery valve	21½ in.
Number of feed pumps (single-acting)	2
Diameter of feed pump plunger	12 in.
Stroke of feed pump plunger	2.482 ft.

THE SCREW

The screw, of bronze, placed in the deadwood of the vessel, was a true helicoid; its pitch was constant at all points of its propelling surface, and the forward and after edges of its blades were parallel when viewed in projection on a plane parallel to the axis. The blades were curved backwards.

The original intention was to give the screw an expanding pitch, the mean of which was to be 25 feet. It was cast from a wooden pattern (the same pattern being used for each blade), but the pattern makers, not being skilled in such work, got the pitch uniform, and by careful measurement of the cast blades it was 28 feet. The entire screw was in a single casting. The following are the dimensions: —

Diameter of the screw	18 ft.
Diameter of the hub	2 ft. 10 in.
Pitch of the screw (uniform)	28 ft.
Number of blades	4
Uniform length of the blades in the direction of the axis	2 ft. 6 in
Fraction used of the pitch	0.357
Helicoidal area of the screw	126.469 sq. ft.
Projected area of the screw on a plane at right angles to axis	89.940 sq. ft.
Projected area of the screw on a plane parallel to axis	80.833 sq. ft.
Radius of the centre of pressure of the screw	7.169 ft.

THE BOILERS

The boilers were arranged in two groups, one forward of the engines, and the other abaft. The boilers of each group were six in number, making twelve boilers in all. Each group consisted of four main boilers and two superheating boilers. All the boilers were arranged in pairs opposite each other and separated by a fire-room extending in the forward and aft direction of the vessel. Each pair of the main boilers had a chimney in common, placed at the centre of their length, and with its axis over the centre line of the fire-room. The superheating boilers of each group were placed next the engines and delivered their products of combustion into the nearest end of the adjacent main boilers. Each group of boilers, therefore, was composed of one superheating and two main boilers on one side of the vessel, and of one superheating and two main boilers on the other side, the products of combustion being delivered into two chimneys. The whole of the steam from the main boilers was passed through the superheating boilers.

All the main boilers were of the vertical water-tube kind, with the tubes arranged over the furnaces. All the superheating boilers had horizontal fire-tubes arranged above their furnaces.

The two after main boilers of the forward group and the two forward main boilers of the after group were exactly alike. The two forward main boilers of the forward group and the two after main boilers of the after group were also exactly alike, except in the number of their furnaces, the forward main boilers of the forward group having seven furnaces and a breadth of 24 feet 4 inches, while the after main boilers of the after group had only six furnaces and a breadth of 20 feet 11 inches. All the superheating boilers were exactly alike.

The fire-room was 9 feet wide, except between the forward main boilers of the forward group and the after main boilers of the after group, the fronts of which inclined towards the keelson enough to make the fire-room only 8 feet 6 inches wide there. All the boilers had their tops in the same horizontal plane; but, as the forward main boilers of the forward group and the after main boilers of the after group had a less height than the other main boilers, namely, 9 feet 5 inches, instead of 10 feet, 8 inches, their bottoms were the difference above the bottoms of the others, namely, 1 foot 3 inches.

None of the boilers had any steam-drum, nor had they any appendage of any kind projecting above their tops, which were 2 feet below the water-line of the vessel.

The distance between the superheating boilers and their adjacent main boilers, on the same side of the vessel, was

6 inches in the clear, and the distance between the main boilers of each group on the same side of the vessel was 3 feet 6 inches, which space was occupied by a T extension of the coal bunkers lying behind the boilers, thus furnishing easy access to the coal of those bunkers from the middle of the fire-rooms.

The extreme length occupied in the vessel by the forward group of boilers was 56 feet 6 inches, and by the after group of boilers 53 feet 1 inch, including the spaces separating the boilers of each group on the same side of the vessel. The extreme breadth occupied in the vessel by the boilers, including the fire-room, was 29 feet 6 inches.

The line-shafting extended through the centre of the fire-room of the after group of boilers, and was sufficiently high above its floor to allow the furnaces to be fired from beneath it.

The stop-valves and steam pipes were so arranged that any boiler could be used alone, or any number of boilers could be used together, and the steam could be used in either the saturated or superheated state.

The following is a detailed description of the boilers, in which will be considered, first, the two after main boilers of the forward group and the two forward main boilers of the after group:—

The shells were rectangular in form, 24 feet 4 inches wide, 10 feet 8 inches high, and 10 feet 3 inches long at the level of the top of the furnaces, and 11 feet 9 inches long at the top of the shell. The vertical sides were joined to the flat bottom by quadrantal curves of 3 inches radius, and to the flat top by quadrantal curves of 20 inches radius. The vertical back was joined to the flat top by a quadrantal curve of 20 inches radius. The bottom was flat for a length of 7 feet from the front, thence it sloped backwards and upwards for a vertical height of 21 inches and a horizontal length of 12½ inches, from which a quadrantal curve of 22 inches radius connected it tangentially with the vertical back. The front of the shell was vertical from the bottom to the bottom of the uptake, that is, for a height of 4 feet 3 inches. From this point it sloped outwards, overhanging the vertical part 18 inches, and being joined tangentially to the flat top by a quadrantal curve of 20 inches radius.

Each shell contained seven furnaces, each 3 feet wide in the clear, and fitted with a grate 7 feet long. They were semicircular on top, and 38 inches high in the clear from the crown to the ash-pit. Their vertical sides were joined to the ash-pit bottom by quadrantal curves of 9 inches radius. The opening for the furnace door was 18 inches wide, semicircular on top, and 17 inches high. The top of the grate-bars was, at the front of the furnaces, 16 inches above the bottom of the ash-pits, and, at the back of the furnaces, 12 inches. The grate-bars were cast in two lengths. They were ⅝ inch wide on top, with ⅝-inch wide air spaces between them. The opening for the furnace door was surrounded by a cast iron frame with ornamental mouldings, and a faced strip for the door to close air-tight against. The door was of cast iron made with a projection of the form and dimensions of the opening. Over this projection was bolted a wrought iron lining-plate perforated with as many holes of 3-16-inch diameter as could be drilled through it for the distribution of the air admitted through seventeen holes of 1¾-inch diameter in the door. The door had a faced strip cast on it to close air-tight against the corresponding strip on the door frame.

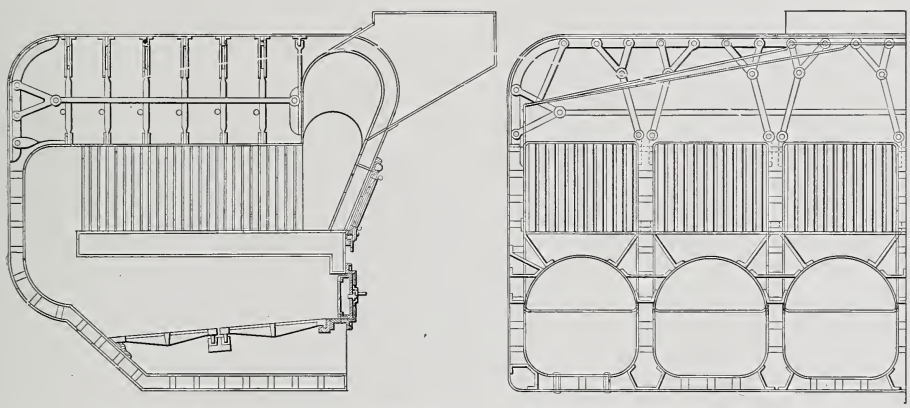
The flat water spaces beneath the ash-pits, between the furnaces, and between the furnaces and shell were 5 inches wide, including thicknesses of metal. Immediately behind each furnace was a short combustion chamber, 6 inches long and 17 inches high in the clear. It was a horizontal extension of the top of the furnace, 36 inches wide in the clear, and had a flat bottom joined to the nearly semicircular top by quadrantal curves of 3 inches radius. The flat water-spaces surrounding the combustion chambers were 5 inches wide, including thicknesses of metal.

Each furnace had a separate back smoke connection joining the combustion chamber and tube-box. The latter

was rectangular, 33½ inches high in the clear, 36 inches wide in the clear, and 7 feet long. The top and bottom of this box were the upper and lower tube-plates, around which the tubes were expanded on one side and riveted over on the other. The lower tube-plate, or bottom of the tube-box, was 8 inches above the crown of the furnace at the front and 7 inches above it at the back, including thicknesses of metal. The flat water-spaces between the tube-boxes and between them and the sides of the shell were 5 inches wide, including thicknesses of metal.

Each tube-box contained twenty-nine rows of tubes lengthwise the boiler, and eleven rows crosswise. The tubes were through which were received the products of combustion from the superheating boiler. The back of the uptake was vertical, and its front was inclined over the fire-room parallel to the shell and 5 inches from it, including thicknesses of metal. The back and front were joined by a semicircular curve with radii continuously increasing from 11 inches at the uptake ends to 15 inches at the openings into the chimney.

The front of the uptake had six inclined water-legs, one opposite each water-space between the tube-boxes. These legs were 5 inches square in cross-section, including thicknesses of metal. The openings between these legs, and between them and the ends of



THE MAIN BOILERS OF THE "WAMPANOAG." LONGITUDINAL AND CROSS SECTION

of brass, seamless, 2 inches in outside diameter, 1 4-5 inches in inside diameter, and 33½ inches in length between the tube-plates, which were ½ inch thick each. Crosswise the boiler, the spaces between the tubes, and between them and the sides of the tube-boxes, were 1⅛ inches in the clear; lengthwise the boiler the spaces between the tubes were ¾ inch in the clear.

The uptake of each boiler served all its furnaces. The bottom was flat, 17 inches long lengthwise the boiler from its front edge. The width of the uptake was 23 feet 6 inches crosswise the boiler. The ends were vertical, and the one adjacent the superheating boiler had a rectangluar opening, 2 feet 9 inches high and 8 inches wide in the clear, the uptake, were rectangular in form, 36 inches wide in the clear and 24 inches high. They were surrounded with cast-iron frames, which had ornamental mouldings and a raised strip, faced for the uptake-doors to close air-tight against. These doors were of cast iron with a raised strip, faced to close air-tight against the corresponding strip on the frame. They were hinged on the top, and had a wrought iron lining-plate on the inside, 1½ inches from the door, and the space between was filled with plaster of Paris and ashes. On the outside was a shield plate, 1½ inches distant, also to protect the firemen from the heat radiated from the doors.

The chimneys were stationary, that is, they were not telescopic. There

was one chimney in common to each pair of opposite boilers. It was 66 feet 8 inches high above the level of the grates, and 7 feet 8 inches in inside diameter. Each chimney was provided with a steam-jet, and its base rested on sheet iron work, projected from the shells and lined with firebrick.

Each boiler had a system of cast iron dry-pipes extending from the stop-valve controlling the egress of the steam to the main steam-pipe. These pipes were placed as near as practicable to the top of the boiler, and were perforated along the entire length on their upper side with holes ¼ inch in diameter and sufficient in number to make up, by their aggregate area, the area of the steam-pipe.

Each boiler was provided with elliptical manholes, 11 and 15 inches, placed in the spandrels between the crowns of the furnaces, and between the crowns of the furnaces and the ends of the shell. Two similar manholes were placed, one at each end of the shell, and opening into the fire-room. Hand-holes were also placed in the spandrels between the bottoms of the ash-pits, and between those bottoms and the end of the shell.

The boilers were double riveted and braced for a working pressure of forty pounds per square inch above the atmosphere, the hydrostatic test pressure applied being sixty-five pounds per square inch. The bottoms of the shell and for 18 inches up the sides were of 7-16-inch thick plate iron. The ash-pits were of 7-16-inch thick iron plate also. The furnaces and bottoms of smoke connections were of ⅜-inch iron plate, and the tube-plates of ½-inch iron. All other plates were of 5-16-inch iron.

The top, sides and back of the shell were stiffened by T iron, placed 12 inches from centre to centre, and extending 9 inches below the upper tube-plate. Such iron was also placed on the vertical back of the uptake above the upper tube-plate. The T iron was 3 by 3½ inches by ⅝ inch, and to it the principal bracing was attached at points not exceeding 12 inches apart. All other portions of the boiler had braces of ⅞ inch diameter placed 8 inches between centres. The boilers were completely covered with thick felt stitched to canvas, over which was a covering of sheet lead from the tops of the boilers to their vertical sides. The following are the principal dimensions and proportions:—

Number of boilers	4
Length of each boiler at the furnaces	10 ft. 3 in.
Length of each boiler on top	11 ft. 9 in.
Breadth of each boiler	21 ft. 4 in.
Height of each boiler	10 ft. 8 in.
Aggregate number of furnaces	28
Breadth of each furnace	3 ft.
Length of grate in each furnace	7 ft.
Aggregate area of grate surface	588 sq. ft.
Aggregate number of tubes (brass)	8,932
Length of each tube between tube-plates	2 ft. 9½ in.
External diameter of each tube	2 in.
Internal diameter of each tube	1 4–5 in.
Number of chimneys	2
Height of each chimney above level of grates	66 ft. 8 in.
Diameter of each chimney	7 ft. 8 in.
Distance traversed by the products of combustion from the centre of the furnace to their delivery into the boiler uptake	15 ft.
Aggregate cross area of the combustion chambers	91.19 sq ft.
Aggregate cross area between tubes for draught	91.19 sq. ft.
Aggregate cross area of the chimnies	92.33 sq. ft.
Aggregate water-space up to highest point of upper tube-plate	2,267.9 cu. ft.
Aggregate water-space up to 9 inches above highest point of upper tube-plate	2,932.1 cu. ft.
Aggregate steam-space above the highest point of upper tube-plate	3,240.7 cu. ft.
Aggregate steam-space above 9 inches above the highest point of upper tube-plate	2,576.5 cu. ft.
Aggregate water heating surface in the furnaces	1,289.17 sq. ft.
Aggregate water heating surface in the combustion chambers	125.22 sq. ft.
Aggregate water heating surface in the back smoke-connections	866.43 sq. ft.
Aggregate water heating surface in the tube-boxes	1,880.86 sq. ft.
Aggregate water heating surface in the tubes, calculated for their outer circumference	13,049.35 sq. ft.
Aggregate water heating surface in the uptakes to top of upper tube-plate	346.30 sq. ft.
Aggregate water heating surface in the uptakes between top of upper tube-plate and 9 inches above that plate	132.67 sq. ft.
Total area of water heating surface	17,690.00 sq. ft.
Aggregate steam superheating surface from 9 inches above top of upper tube-plate	407.50 sq. ft.
Ratio of the water heating surface to the grate surface	30.085 to 1.000
Ratio of the steam superheating surface to the grate surface	0.693 to 1.000
Ratio of the grate surface to the cross area of the combustion chambers	6.448 to 1.000
Ratio of the grate surface to the cross area for draught between the tubes	6.448 to 1.000
Ratio of the grate surface to the cross area of the chimneys	6.369 to 1.000

In the case of the two forward main boilers of the forward group the shells

also were rectangular in form, 24 feet 4 inches wide, 9 feet 5 inches high, and 9 feet ½ inch long at the level of the top of the furnaces, and 10 feet 6 inches long at the top of the shell. The vertical sides were joined to the flat bottom by quadrantal curves of 3 inches radius, and to the flat top by quadrantal curves of 18 inches radius. The vertical back was joined to the flat top by a quadrantal curve of 18 inches radius. The bottom was flat for a length of 5 feet 6 inches, thence it sloped backwards and upwards for a vertical height of 21 inches and a horizontal length of 23 inches, from which a quandrantal curve of 22 inches connected it tangentially with the vertical back. The front of the shell was vertical from the bottom to the bottom of the uptake, that is, for a height of 4 feet 3 inches; from this point it sloped outwards, overhanging the vertical part 17½ inches, and being joined tangentially to the flat top by a quadrantal curve of 18 inches radius.

Each shell contained seven furnaces, each 3 feet wide in the clear, and fitted with a grate 6 feet long. They were semicircular on top, and 38 inches high in the clear from the crown to the ash-pit. Their vertical sides were joined to the ash-pit bottom by quadrantal curves of 9 inches radius. The opening for the furnace door, the door itself, the grate-bars, and all details were the same as described for the furnaces of the other main boilers of this group. The flat water-spaces beneath the ash-pits, between the furnaces, and between the furnaces and shell, were 5 inches wide, including thicknesses of metal.

There were no combustion chambers, and the back smoke-connections joined the furnaces directly to their tube-boxes. Each furnace had a separate back smoke-connection. The bottom of the connection was a quadrantal curve of 17 inches radius joining the vertical back tangentially; and the flat top was joined to the vertical back by a quadrantal curve of 9 inches radius. The sides were vertical. The height of the connection in the clear was 52 inches; its width crosswise the boiler was 36 inches in the clear; and its length lengthwise the boiler, 17 inches in the clear. The flat water-spaces between the back smoke-connections, and between them and the shell, were 5 inches wide, including thicknesses of metal.

Immediately over each furnace was a rectangular tube-box, 28 inches high in the clear, 36 inches wide in the clear, and 6 feet 1 inch long. The top and bottom of this box were the upper and lower tube-plates around which the tubes were expanded on one side and riveted over on the other. The lower tube-plate or bottom of the tube-box was 8 inches above the crown of the furnace at the front, and 7 inches above it at the back, including thicknesses of metal. The flat water-spaces between the tube-boxes, and between them and the sides of the shell, were 5 inches wide, including thicknesses of metal.

Each tube-box contained twenty-five rows of tubes lengthwise the boilers, and eleven rows crosswise. The tubes were of brass, seamless, 2 inches in outside diameter, 1 4-5 inches in inside diameter, and 28 inches in length between the tube-plates, which were ½ inch thick each. Crosswise the boiler, the spaces between the tubes, and between them and the sides of the tube-boxes, were 1⅛ inches in the clear; lengthwise the boiler the spaces between the tubes were ¾ inch in the clear.

The uptake of each boiler was common to all its furnaces. The bottom was flat, 13½ inches long lengthwise the boiler from its front edge. The width of the uptake was 23 feet 6 inches crosswise the boiler. The ends were vertical. The back of the uptake was vertical, and its front was inclined over the fire-room parallel to the shell and 5 inches from it, including thicknesses of metal. The back and front were joined by a semicircular curve with radii continuously increasing from 9½ inches at the uptake ends to 13 inches at the openings into the chimney. The front of the uptake had six inclined water-legs, one opposite each water-space between the tube-boxes. These legs were 5 inches square in cross-section, including thicknesses of metal. The openings

between these legs, and between them and the ends of the uptake, were rectangular in form, 36 inches wide in the clear and 19 inches high. They were surrounded with cast-iron frames which had ornamental mouldings and a raised strip faced for the uptake-doors to close air-tight against. The uptake-doors were the same as described for those of the other main boilers of this group.

The chimney served for both boilers. It was 65 feet 5 inches high above the level of the grates, and 6 feet 6 inches in inside diameter. It was provided with a steam-jet, and its base rested on sheet iron work projected from the shell and lined with fire-brick. The dry-pipes, manholes, hand-holes, bracing, thicknesses of plate iron, riveting and felting were precisely the same as described for the other main boilers of this group. The following were the principal dimensions and proportions:—

Number of boilers	2
Length of each boiler at the furnaces	9 ft. ½ in.
Length of each boiler on top	10 ft. 6 in.
Breadth of each boiler	24 ft. 4 in.
Height of each boiler	9 ft 5 in.
Aggregate number of furnaces	14
Breadth of each furnace	3 ft.
Length of grate in each furnace	6 ft.
Aggregate area of grate surface	252 sq. ft.
Aggregate number of tubes (brass)	3,850
Length of each tube between tube-plates	2 ft. 4 in.
External diameter of each tube	2 in.
Internal diameter of each tube	1 4-5 in.
Number of chimneys	1
Height of the chimney above the level of the grates	65 ft. 5 in.
Diameter of the chimney	6 ft. 6 in.
Distance traversed by the products of combustion from the centre of the furnace to their delivery into the uptake	12 ft. 9 in.
Aggregate cross area over the bridge-walls of the furnaces	45.59 sq. ft.
Aggregate cross area between tubes for draught	38.11 sq. ft.
Cross area of the chimney	33.18 sq. ft.
Aggregate water-space up to highest point of upper tube-plate	957.8 cu. ft.
Aggregate water-space up to 9 inches above highest point of upper tube-plate	1,281.9 cu. ft.
Aggregate steam-space above the highest point of the upper tube-plate	1,160.3 cu. ft.
Aggregate steam-space above 9 inches above the highest point of the upper tube-plate	836 2 cu. ft.
Aggregate water heating surface in the furnaces	603.65 sq. ft.
Aggregate water heating surface in the back smoke-connections	399.20 sq. ft.
Aggregate water heating surface in the tube-boxes	740.54 sq. ft.
Aggregate water heating surface in the tubes, calculated for their outer circumference	4,703.68 sq. ft.
Aggregate water heating surface in the uptakes to top of upper tube-plate	148.96 sq. ft.
Aggregate water heating surface in the uptakes between top of upper tube-plate and 9 inches above that plate	68.97 sq. ft.
Total area of water heating surface	6,665.00 sq. ft.
Aggregate steam superheating surface from 9 inches above top of upper tube-plate	154.7 sq. ft.
Ratio of the water heating surface to the grate surface	26.448 to 1.000
Ratio of the steam superheating surface to the grate surface	0.614 to 1.000
Ratio of the grate surface to the cross area over the bridge-wall of the furnace	5.527 to 1.000
Ratio of the grate surface to the cross area for draught between the tubes	6.612 to 1.000
Ratio of the grate surface to the cross area of the chimney	7.595 to 1.000

With the exception of having one furnace and the flat water-space by its side, less, the two after main boilers of the after group were precisely the same as the two forward main boilers of the forward group just described. This difference of one furnace less in the breadth of these boilers made their shells 20 feet 11 inches wide instead of 24 feet 4 inches, reduced the width of the combustion chamber from 23 feet 6 inches to 20 feet 1 inch in the clear, and the diameter of the chimney from 6 feet 6 inches to 6 feet 3 inches in the clear.

The following were the principal dimensions and proportions:—

Number of boilers	4
Length of each boiler at the furnaces	9 ft. ½ in.
Length of each boiler on top	10 ft. 6 in.
Breadth of each boiler	20 ft. 11 in.
Height of each boiler	9 ft. 5 in.
Aggregate number of furnaces	12
Breadth of each furnace	3 ft.
Length of grate in each furnace	6 ft.
Aggregate area of grate surface	216 sq. ft.
Aggregate number of tubes (brass)	3,300
Length of each tube between tube-plates	2 ft. 4 in.
External diameter of each tube	2 in.
Internal diameter of each tube	1 4-5 in.
Number of chimneys	1
Height of the chimney above level of grates	65 ft. 5 in.
Diameter of the chimney	6 ft. 3 in.
Aggregate cross area over the bridge-walls of the furnaces	39.08 sq. ft.
Aggregate cross area between tubes for draught	32.67 sq. ft.
Cross area of the chimney	30.68 sq. ft.
Aggregate water-space up to highest point of upper tube-plate	826.6 cu. ft.
Aggregate water-space up to 9 in. above highest point of upper tube-plate	1,105.9 cu. ft.
Aggregate steam-space above the highest point of the upper tube-plate	998.1 cu. ft.
Aggregate steam-space above 9 in. above the highest point of the upper tube-plate	718.8 cu. ft.
Aggregate water heating surface in the furnaces	517.42 sq. ft.
Aggregate water heating surface in the back smoke-connections	342.17 sq. ft.
Aggregate water heating surface in the tube-boxes	634.75 sq. ft.
Aggregate water heating surface in the tubes, calculated for their outer circumference	4,031.72 sq. ft.

Aggregate water heating surface in the uptakes to top of upper tube-plate	127.95 sq. ft.
Aggregate water heating surface in the uptakes between top of upper tube-plate and 9 in. above that plate	58.99 sq. ft.
Total area of water heating surface	5,713.00 sq. ft.
Area of steam superheating surface from 9 in. above top of upper tube-plate	132.8 sq. ft.
Ratio of the water heating surface to the grate surface	26.449 to 1.000
Ratio of the steam superheating surface to the grate surface	0.614 to 1.000
Ratio of the grate surface to the cross area over the bridge-wall of the furnace	5.527 to 1.000
Ratio of the grate surface to the cross area for draught between the tubes	6.612 to 1.000
Ratio of the grate surface to the cross area of the chimney	7.040 to 1.000
Distance traversed by the products of combustion from the centre of the furnace to their delivery into the uptake	12 ft. 9 in.

SYNOPSIS OF THE EIGHT MAIN-BOILERS

Aggregate area of grate surface	1,056.00 sq. ft.
Aggregate area of water heating surface in the furnaces	2,410.24 sq. ft.
Aggregate area of water heating surface in the combustion chambers and back smoke-connections	1,733 02 sq. ft.
Aggregate area of water heating surface in the tube-boxes	3,256.15 sq. ft.
Aggregate area of water heating surface in the tubes	21,784.75 sq. ft.
Aggregate area of water heating surface in the uptakes up to 9 in. above the highest point of the upper tube plates	883.84 sq. ft.
Total area of water heating surface	30,068.00 sq. ft.
Total area of steam superheating surface	605.00 sq. ft.
Aggregate area over the bridge-walls of the furnaces	175.86 sq. ft.
Aggregate cross area through the tubes, for draught	161.97 sq. ft.
Aggregate cross area of the chimneys	156.19 sq. ft.
Mean height of the chimneys above the level of the grate-bars	66 1-9 ft.
Aggregate water-space up to 9 in. above the highest point of the upper tube plates	5,319.9 cu. ft.
Aggregate steam space above 9 in. above the highest point of the upper tube-plates	4,131.5 cu. ft.
Ratio of the water heating to the grate surface	28.473 to 1.000
Ratio of the steam superheating to the grate surface	0.658 to 1.000
Ratio of the grate surface to the cross area over the bridge-walls of the furnaces	6.005 to 1.000
Ratio of the grate surface to the cross area between the tubes for draught	6.520 to 1.000
Ratio of the grate surface to the cross area of the chimneys	6.761 to 1.000

The four superheating boilers contained one furnace each and were intended to be fed with sea water. The lower portion of the heating surface in these boilers was water-heating surface, and the upper portion was steam superheating surface, so that they furnished steam as well as superheated it, and could be used alone, as auxiliary boilers, when the vessel was at anchor, to distill potable water, to work the auxiliary steam pumps to pump out the bilge water, and to furnish steam for heating the vessel.

They also had another very important use. When fed with sea water they furnished the main boilers with the necessary distilled water to compensate the inevitable loss of feed-water by the latter, due to various causes, so that the main boilers could be supplied entirely with pure water, and could be kept free from scale, and protected from the internal corrosion caused by the use of sea water feed even in the small proportion needed for supplying the distilled water deficit. The same object has been sought to be attained in later ocean steamers by the use of evaporators, but the superheating boilers of the *Wampanoag* had this economic superiority, that the additional steam furnished by them from sea water produced its full power effect in the engines before being liquefied in the condenser to supply the deficit of distilled water. In the case of evaporators, the distillate produces no power effect in the engines, and merely supplies the feed-water deficit. The deposition of scale in the superheating boilers is about the same as in the evaporators, and in both cases must be reduced in quantity by "blowing out," and the remainder removed by mechanical means. In practical simplicity the superheating boilers are as superior to evaporators as they are in economic effect.

The superheating surfaces consisted, in each boiler, of one smoke-connection, part of another, part of the uptake, and two groups of wrought iron horizontal fire-tubes, one group lying immediately over the other, and both lying above the furnace, from which they were separated by three horizontal cylindrical flues whose surfaces were water-heating surfaces. The furnace, the combustion chamber, one smoke-connection and part of another, and part of the uptake were also water-heating surfaces. The water level was carried between the flues and the tubes.

The shell was rectangular with flat top and bottom, and vertical front, back,

and ends. It was 3 feet 10 inches wide, 10 feet 3 inches long, and 10 feet 8 inches high. The top was joined to the back and ends with quadrantal curves of 20 inches radius, and to the front by a square corner. The bottom was horizontal for 6 feet from the front; thence it sloped upwards and backwards, rising 21 inches in a horizontal distance of 13½ inches. From this point it was horizontal for a distance of 15½ inches, and then was joined to the vertical back by a quadrantal curve of 22 inches radius. The vertical ends were joined to the bottom by quadrantal curves of 2 inches radius.

The furnace had a semicircular top. It was 3 feet wide in the clear and 6 feet long; all its surfaces were water-heating surfaces. The height from the crown to the bottom of the ash-pit was 38 inches, and its vertical sides were joined to the flat bottom of the latter by quadrantal curves of 9 inches radius. The opening for the furnace door, the door itself, the grate-bars, and all their details were precisely like those described for the main boilers. The flat water-spaces beneath the ash-pit and between the furnace and the shell were 5 inches wide, including thicknesses of metal.

The top of the combustion chamber was a horizontal continuation of the top of the furnace. It was a segment of a circle of 36 inches diameter, and its height was 17 inches in the clear. The bottom was flat, and joined tangentially to the top by curves of 3 inches radius. The flat water-space beneath the chamber was 5 inches wide, including thicknesses of metal. The chamber was 18 inches long, and all its surfaces were water-heating surfaces.

The lower back smoke-connection was rectangular in form, 17 inches long lengthwise the boiler, 32 inches high, and 36 inches wide in the clear. The flat top was joined to the vertical back by a quadrantal curve of 9 inches radius, and the bottom was composed of a quadrantal curve of 17 inches radius joining tangentially the vertical back with the horizontal bottom of the combustion chamber. The flat water-spaces between the connection and the shell were 5 inches wide, including thicknesses of metal.

From the lower back smoke-connection there were returned immediately above the furnace three horizontal flues of 10 inches inner diameter, and 6 feet 4 inches length. The water-space between the crown of the furnace and the bottom of the flues was 5 inches wide, including thicknesses of metal. The least water-space between the flues was 3 inches wide, including thicknesses of metal. The water-line in the boiler was carried 3 inches above the top of the flues, all of whose surfaces were, of course, water-heating surfaces.

The flues delivered into the front smoke-connection, which was rectangular in form, 9 inches long lengthwise the boiler, 36 inches wide, and 42½ inches high in the clear. The flat bottom was joined to the vertical ends by quadrantal curves of 5¼ inches radius. The front was composed of a cast iron door hinged at the top and secured at the bottom with catches. It closed air-tight by means of a faced strip against a corresponding strip on a cast iron frame secured to the boiler. The door had a wrought iron lining-plate, and the space, two inches wide, between them was filled with plaster of Paris and ashes. The lower part of this connection was water-heating surface, and the upper part was steam superheating surface.

From the upper part of the front smoke connection there were returned from the front towards the back of the boiler ninety-six horizontal, lap-welded, iron, steam superheating fire-tubes of 2 inches outside diameter, 1¾ inches inside diameter, and 6 feet 3 inches length between the tube plates, which were of ½ inch thick iron. These tubes were distributed into twelve rows horizontally and eight rows vertically.

The upper back smoke-connection was immediately over the lower back smoke-connection, from which it was separated by a space 3 inches wide, including thicknesses of metal. It was rectangular in form, 17 inches long lengthwise the boiler, 36 inches wide, and 61½ inches high in the clear. The

flat top was joined to the vertical back by a quadrantal curve of 15 inches radius, and the flat bottom was joined to the vertical back by a quadrantal curve of 9 inches radius. The connection was on all sides separated from the shell by spaces 5 inches wide, including thicknesses of metal. All the surfaces of this connection were superheating surfaces.

From the upper part of the upper back smoke-connection there were returned from the back towards the front of the boiler ninety horizontal, lap-welded, iron, steam superheating fire-tubes of 2 inches outside diameter, 1¾ inches inside diameter, and 7 feet length between tube-plates, which were of ½ inch thick iron. These tubes were immediately over those above described, and were distributed into twelve rows horizontally and eight rows vertically, the upper row lacking four tubes and the row next to the upper one lacking two tubes on account of the curvature of the top of the boiler.

The uptake was rectangular in form, and occupied the whole front of the boiler above the furnace. It was 16 inches long in the clear lengthwise the boiler, 36 inches wide, and 6 feet 3 inches high in the clear. The front of the uptake was closed by two doors, hinged on the sides, and secured by latches in the centre. The doors were of cast iron and fitted air-tight by means of a faced strip or edge closing against a corresponding strip on a cast iron frame secured to the boiler. They had a wrought iron lining-plate, and the intermediate space was filled with a mixture of plaster of Paris and ashes. In the lower part of the uptake, on the side next to the adjacent main boiler, was a rectangular aperture, 33 inches high and 8 inches wide, through which the products of combustion from the superheating boiler passed into the end of the uptake of the main boiler, which had a corresponding aperture to admit them. The connection between these two apertures was a rectangular flue of the same section, formed of boiler plate and surrounded by a sleeve of boiler plate, leaving a space of 3 inches width between them, which was filled with fire-clay. The lower part of the uptake was water-heating surface, and the upper part steam superheating surface. The flat spaces separating the uptake from the shell of the boiler on each side were 5 inches wide, including thicknesses of metal.

The riveting, thickness of plate iron, bracing, felting, manholes and hand-holes were the same as described for the main boilers. There was a manhole in each spandrel of the furnace, and a hand-hole in each spandrel of the ash-pit. The following were the principal dimensions and proportions of the superheating boilers:—

Number of boilers	4
Length of boiler	10 ft. 3 in.
Breadth of boiler	3 ft. 10 in.
Height of boiler	10 ft. 8 in.
Aggregate number of furnaces	4
Width of each furnace	3 ft.
Length of grate-bars	6 ft.
Aggregate area of grate surface	72 sq. ft.
Aggregate number of flues	12
Internal diameter of flues	10 in.
Extreme length of flues	6 ft. 4 in.
Aggregate number of tubes in lower groups (iron)	384
External diameter of tubes of lower groups	2 in.
Internal diameter of tubes of lower groups	1¾ in.
Length of tubes of lower groups between tube-plates	6 ft. 3 in.
Aggregate number of tubes in upper groups (iron)	360
External diameter of tubes of upper groups	2 in.
Internal diameter of tubes of upper groups	1¾ in.
Length of tube of upper groups between tube-plates	7 ft.
Aggregate area of water heating surface in the furnaces	146.52 sq. ft.
Aggregate area of water heating surface in the combustion chambers	49.29 sq. ft.
Aggregate area of water heating surface in the lower back smoke-connections	94.63 sq. ft.
Aggregate area of water heating surface in the flues	198.87 sq. ft
Aggregate area of water heating surface in the front smoke-connection and in the uptake	21.69 sq. ft.
Total water heating surface up to 3 inches above top of flues	511.00 sq. ft.
Aggregate steam superheating surface in the front smoke-connections	42.61 sq. ft.
Aggregate steam superheating surface in the tubes of the lower groups calculated for their inner circumference	1,099.56 sq. ft.
Aggregate steam superheating surface in the upper back smoke-connections	184.70 sq. ft.
Aggregate steam superheating surface in the tubes of the upper groups	1,154.54 sq. ft.
Aggregate steam superheating surface in the uptakes	111.59 sq. ft.
Total steam superheating surface above 3 inches above top of flues	2,593.00 sq. ft.
Aggregate cross area of the combustion chambers	13.03 sq. ft.
Aggregate cross area of the flues	6.545 sq. ft.

Aggregate cross area of the tubes of the lower groups	6.414 sq. ft.
Aggregate cross area of the tubes of the upper groups	6.013 sq. ft.
Aggregate area of the apertures for the egress of the products of combustion into the uptakes of the main-boilers	7.333 sq. ft.
Aggregate water-room up to 3 inches above top of flues	297.3 cu. ft.
Aggregate steam-room above 3 inches above top of flues	463.0 cu. ft.
Distance traversed by the products of combustion from the centre of the furnace to their delivery into the uptake	32 ft. 6 in.
Ratio of the water heating to the grate surface	7.097 to 1.000
Ratio of the grate surface to the cross area of the cumbustion chambers	5.526 to 1.000
Ratio of the grate surface to the cross area of the flues	11.001 to 1.000
Ratio of the grate surface to the cross area of the tubes of the lower group	11.225 to 1.000
Ratio of the grade surface to the cross area of the tubes of the upper group	11.974 to 1.000
Ratio of the grate surface to the area of the apertures for the egress of the products of combustion into the uptakes of the main-boilers	9.818 to 1.000

PRINCIPAL QUANTITIES OF THE AGGREGATE MAIN AND SUPERHEATING BOILERS

Area of grate surface	1,128 sq. ft.
Area of water heating surface	30,579 sq. ft.
Area of steam superheating surface	3,288 sq. ft.
Ratio of water heating surface to grate surface	27.109 to 1.000
Ratio of steam superheating surface to grate surface	2.915 to 1.000
Water-room	5,617.2 cu. ft.
Steam-room	4,594.5 cu. ft.

In the following tables will be found the data and results of the trials of the *Wampanoag*, made under different conditions of draught of water, state of the sea, kind and direction of the wind, speed of the vessel, etc., all of which naturally varied for sea trials made at considerable intervals of time. They give also the data and results of the trial of the machinery with the vessel secured to the dock.

The trials at sea were all made in precisely the same manner and by the same persons. In none of the trials were the bunkers entirely filled with coal. The whole of the armament was on board, but not its full complement of ammunition; neither were there stores, provisions, etc., for six months' use. The boats, anchors, cables, masts, spars, rigging, sails, etc., were all in place. The personnel were all on board. In fact, all the weights were full, except coal, provisions and ammunition, which three items were less than full.

During the maximum performance between the cities of New York and Charleston the following were the weights on board; that is, not the weights at the commencement of the trial, but the average weights during the trial:—

Hull	1,975	tons.
Masts, spars, rigging, sails, etc.	110	"
Boats, anchors, cables, etc	60	"
Armament	51	"
Ammunition	15	"
Stores, provisions, water, etc	71	"
Personnel	28	"
Machinery, etc	1,250	"
Coal in bunkers	215	"
Total displacement	3,775	tons.

The full weights were as follows:—

Hull	1,975	tons
Masts, spars, rigging, sails, etc	110	"
Boats, anchors, cables, etc	60	"
Armament	51	"
Ammunition	48	"
Stores, provisions, water, etc., for six months	178	"
Personnel and effects	28	"
Machinery, etc	1,250	"
Coal in bunkers	750	"
Total displacement	4,450	"

This corresponded to a mean deep load draught of water of 20 feet 6⅔ inches. The mean draught of water during the maximum performance was 18 feet 5 inches.

During all the trials the vessel was under steam alone, no sail being set. The speed was ascertained by the ship log and by the patent log, the former being hove half-hourly, and the latter being observed half-hourly. There was very little difference in their mean indications. Also, the speed was simultaneously determined by observations on the lighthouses along the coast, the positions of which are accurately known from the Coast Survey charts. The speed, as obtained by these means, was reported to the Navy Department by the commanding officer of the vessel, the distances run, and the times of running being those given in the tables. The patent log remained permanently in the water and registered the speed on board by a counter that showed the distance run at any moment by inspection. This log was very accurate, giving exact results when tested by running known distances between lighthouses on the coast. The vessel's draught of water forward and aft was taken carefully at the beginning and the end of each trial.

The steam machinery was under the

direction of Chief Engineer Theodore Zeller, U. S. Navy. Under him were two chief engineers and sixteen assistant engineers, who personally made all the observations required and entered them in a tabular log every half hour. The coal consumed was carefully weighed on scales, and the number of pounds consumed was entered hourly in the log. At the end of every half hour an indicator diagram was taken from each end of the two cylinders. The cylinder pressures given in the tables are the means from all the diagrams taken, every one of which was accurately measured.

The trials were conducted with consummate skill by Chief Engineer Zeller, whose great practical knowledge, energy, and extensive experience made them a complete success. There were no stoppages, no slowings down, no heating of journals, no alterations of the throttle valve, no changes of temperatures or of pressures. The conditions of each trial were uniformly maintained from the beginning to the end, and under the best methods for producing the maximum economy.

Every half hour there were entered in the tabular log by the proper assistant engineers the steam pressure taken from a gauge in the steam pipe near the engines, the vacuum in the condenser, the barometer, the number on the counter, and the number of double strokes made per minute by the pistons, the position of the throttle valve, the temperatures of the external atmosphere, of the engine room, of each fire-room, of the injection and discharge water entering and leaving the condenser, and of the feed-water.

Throughout all the experiments the superheating boilers superheated the steam in them as nearly as possible 30 degrees Fahr.; but this superheating was entirely lost before the steam reached the engines, which it entered in the saturated state by the indications of the thermometers. Doubtless it entered the engines much dryer than if it had not been superheated.

What is called the maximum performance was made with the very moderate rate of combustion of 11.232 pounds of coal consumed per hour per square foot of grate surface. This rate could be easily increased,—natural draught being still employed, for there were no blowers on board,—50 per cent., with an increase of engine power sufficient to increase the speed of the vessel about 10 per cent.; but the object of the trial was to ascertain not the speed of the vessel with the boilers forced to the utmost, but the speed which could be permanently maintained at sea with the number of firemen and coal heavers that could be allowed, and which, with the coal that could be carried, would give the vessel the proper radius of action. She was to have not only a high speed, but the ability to maintain it without either risk of injury to the machinery or of exhaustion of the engineering personnel as long as the coal lasted. With the number of coal heavers on board, no more coal could be delivered on the floors of the fire-rooms, notwithstanding the convenient arrangement of the bunkers. This fact practically limited the speed of the vessel. With a larger force of coal heavers, more coal could easily have been burned, and the speed of the vessel proportionately increased. There was no forced blast provided.

The vessel was designed for a sustained speed of 15 geographical miles per hour in ordinary sea weather and at her load draught of water, according to the programme submitted by the writer to the Navy Department, and this she would do. She exactly confirmed the calculations made for her before she was commenced, which is the real proof of mastery of the subject.

The economy trial was made with a uniform speed of vessel of 11.5 geographical miles per hour, which was the speed at that period of a first-class transatlantic steamer plying between New York and Liverpool. The object was to ascertain practically the consumption of coal per hour at this speed. Only the forward boilers were employed during the trial, and with the slow rate of combustion of 6.947 pounds of anthracite per square foot of grate surface per hour.

The first preliminary trial at sea was

made to ascertain whether the machinery was in proper condition for the final test, and to familiarise the deck and the engine room forces with their experimental duties. It revealed the fact that the division plate dividing one end of the condenser between its head and tubes into two compartments vertically, the lower one receiving the injection water and the upper one delivering the discharge water, had never been secured in place; it simply lay horizontally upon its supporting projections, but had not been bolted to them by the contractors. Consequently it lifted like a valve at each stroke of the piston of the circulating pump, and discharged a considerable portion of the injection water directly through the discharge compartment and overboard, causing the condenser tubes to be correspondingly inoperative. The result was the very poor vacuum in the condenser of 15.07 inches of mercury, the discharge water leaving the condenser with the high temperature of 84.3 degrees, caused by the high temperature of the portion of the discharge water that passed through the tubes.

The temperature of the back pressure steam in the condenser was 179.3 degrees. If the water that passed through the tubes be supposed to have the lower temperature of 160 degrees, and if the water passing the division plate directly had the temperature of the injection, namely, 43.4 degrees, then, approximately, of the total injection water 35 per cent. passed through the tubes liquefying the steam, and the remaining 65 per cent. passed directly overboard without having had any action upon the exhaust steam. Nevertheless, notwithstanding the high back pressure thus caused against the pistons, the economy of the power was not in the least affected, the indicated horse-power being obtained for 2.96 pounds of coal consumed per hour. Several causes operated to produce this unexpected result, which, however, is satisfactorily explainable by a comparison of the data given by the maximum performance with the data of the first preliminary trial.

In the case of the maximum performance the total pressure on the pistons was 38.2 pounds per square inch, of which 34.2 pounds, or 89.53 per cent., were utilised as indicated pressure.

In the case of the first preliminary trial the total pressure on the pistons was 38.07 pounds per square inch, of which 29.07 pounds, or 76.36 per cent., were utilised as indicated pressure. Consequently, from this cause alone there should have been a superior economy with the maximum performance of $\left(\frac{89.53-76.36 \times 100}{76.36}=\right)$ 17.25 per cent.

In the first preliminary trial the boiler pressure was about 54 pounds per square inch above the zero of pressure, and the total heat of the steam was 1201 Fahrenheit units above the Fahrenheit zero, of which, as the temperature of the feed-water was 160 degrees, there were imparted by the fuel 1041 Fahrenheit units, or 86.68 per cent.

During the maximum performance, the boiler pressure was about 49.5 pounds per square inch above the zero of pressure, and the total heat of the steam was 1199.4 Fahrenheit units above the Fahrenheit zero, of which, as the temperature of the feed-water was 138 degrees, there were imparted by the fuel 1061.4 Fahrenheit units, or 88.50 per cent., the difference being 1.82 per cent. in favour of the first preliminary trial.

Now by reason of the less heat by 1.82 per cent. required to be imparted by the fuel to the water in the boiler, the economic evaporating efficiency of the fuel may be supposed to be increased, say, 1.18 per cent., which would make $1.82 + 1.18 = 3$ per cent. to be deducted from the 17.25 per cent., leaving 14.25 per cent. to be accounted for.

Also, in the first preliminary trial the rate of combustion was 7.871 pounds of coal per square foot of grate per hour, while during the maximum performance it was 11.23 pounds. Probably there was an economy of, say, 4.25 per cent. due to this difference, reducing the 14.25 per cent. to 10 per cent. The whole of the latter, and more, can be

accounted for by the reduced cylinder condensation due to the higher temperature of the back pressure against the pistons, and the lower temperature of the indicated pressure, in the case of the first preliminary trial than in the case of the maximum performance.

Further, the cut off during the first preliminary trial was at 0.518 of the stroke of the piston from the commencement, while during the maximum performance it was at two-thirds of the stroke. This difference in the measure of expansion might operate a few points in favour of the first preliminary trial.

The foregoing approximate calculations have been made to show that the practical equality of the economy of the power in the two cases can be easily accounted for, notwithstanding the much less fraction of the total pressure utilised as indicated pressure in the case of the first preliminary trial than in that of the maximum performance, so that there is no reason to be either astonished at the result or to doubt the accuracy of the experimental quantities.

A most important investigation never yet made in steam engineering would be the determination of the highest back pressures which can be used in cylinders working with different regimens of steam without sacrifice of economy, the back pressures having, of course, the temperatures normal to them. This would allow a corresponding reduction in the condenser surface, but would require an increase in the cylinder capacity, but no increase in any other part of the engine. The air pump in the case of the higher temperatures of back pressure would not pump overboard more aqueous vapour to be replaced in the boiler by distillation, because from boiler to engine and back to boiler the cycle was a closed one. The circulating pump, on the contrary, would have to pump less injection water.

After the first preliminary trial Chief Engineer Zeller determined to repeat it with the machinery in the same condition, in order to test the accuracy of the data. The second preliminary trial was thus made and gave substantially the same results as the first, after which the division plate in question was secured in position and the maximum performance and the economic trial were made.

During the latter part of the Civil War the United States Navy Department had great difficulty in getting any of its work done. The private machine shops were overwhelmed with work for the War Department as well as for the Navy Department, for the former had as large a fleet as the latter, reckoned by displacement. The shops refused to accept more work, and what they had taken they very slowly completed. Their plant was not adapted for large machinery, nor could they execute such work properly, and there was no time to introduce improvements. Small work and repairs, of which they had all that their facilities could do, were much more profitable than the large new work of the Navy, taken at a round contract price, and its completion was deferred to that of other work for which the returns were quicker and larger.

Performance of the United States screw sloop *Wampanoag* under steam alone during her trial at sea between the cities of New York and Charleston, at maximum speed, burning a mixture of semi-bituminous coal and anthracite with natural draught. All boilers in use:—

Date of commencing the trial..9 p. m., Feb. 11, 1868

VESSEL		
Average draught of water during trial, in feet	Forward	17.0
	Mean	18.5
	Aft	20.0
Greatest immersed transverse section, in square feet		617.16
Displacement, in tons of 2240 pounds		3,775.00
Immersed external surface of hull, including keel, in square feet		18,754.30
WIND AND SEA		
Kind of wind		Strong breeze
Angle from ahead made by the wind with the vessel's keel, in degrees		132
State of the sea		Rough
TOTAL QUANTITIES		
Duration of the trial, in consecutive hours		33
Number of geographical miles of 6086 feet steamed		553
Number of double strokes made by the pistons of the engines		61,905
Number of revolutions made by the screw		126,830
Number of pounds of coal consumed		418,130
COAL		
Pounds of coal consumed per hour		12,670.606
Pounds of coal consumed per hour per square foot of grate surface		11.232
Fraction of a pound of coal consumed per hour per square foot of heating surface		0.414

TEMPERATURES IN FAHRENHEIT DEGREES

External atmosphere	44
Number of degrees of superheating given to the steam in the superheating boilers	30
Engine room	87
Forward fire-room	95
After fire-room	102
Injection or refrigerating water entering condenser	50
Injection or refrigerating water leaving condenser	77
Hot well or feed water	138

SPEED OF VESSEL AND SLIP OF SCREW

Speed of the vessel per hour in geographical miles of 6086 feet	16 758
Axial speed of the screw per hour in geographical miles of 6086 feet	17 682
Slip of the screw per hour in geographical miles of 6086 feet	0.924
Slip of the screw in per centum of its axial speed	5.225

ENGINES

Number of double strokes made per minute by the pistons of the engines	31.265
Number of revolutions made per minute by the screw	64.055
Steam pressure in the steam pipe near the cylinders, in pounds per square inch above the atmosphere	32.43
Proportion of throttle valve open	1.000
Fraction of stroke of piston completed when the steam was cut off	0.667
Fraction of return stroke of piston completed when the steam was cushioned	0.735
Number of times the steam was expanded	1.453
Vacuum in condenser in inches of mercury	24.00
Barometer in inches of mercury	30.53
Pressure in condenser in pounds per square inch above zero	3.205

STEAM PRESSURES IN CYLINDERS, PER INDICATOR

In pounds per square inch above zero at commencement of stroke of piston	44.0
In pounds per square inch above zero at point of cutting off the steam	41.0
In pounds per square inch above zero at end of stroke of piston	27.0
In pounds per square inch above zero at point where cushioning commenced	3.4
Mean back pressure against the piston, exclusive of the cushioning, in pounds per square inch above zero	4.0
Mean back pressure against the piston of the cushioning alone, in pounds per square inch above zero	8.5
Mean indicated pressure on pistons, in pounds per square inch	34.2
Mean net pressure on pistons, in pounds per square inch	32.7
Mean total pressure on pistons, in pounds per square inch above zero	38.2

POWER DEVELOPED

Indicated horse-power developed by the engines	4,048.840
Net horse-power developed by the engines	3,871.259
Total horse-power developed by the engines	4,522.389

ECONOMY OF THE POWER

Pounds of coal consumed per hour per indicated horse-power	3.129
Pounds of coal consumed per hour per net horse-power	3.273
Pounds of coal consumed per hour per total horse-power	2 802

WEIGHT OF STEAM, PER INDICATOR

Pounds weight of steam drawn from the boilers per hour, calculated from the pressures in the cylinders at the point of cutting off the steam, and at the point at which the cushioning commenced. The steam supposed to be saturated	115,429.416

DISTRIBUTION OF THE NET HORSE-POWER

Horse-power overcoming the friction of the load	290.344
Horse-power overcoming the friction of the water on the screw blades	276.500
Horse-power expended in the slip of the screw	172.655
Horse-power expended in the propulsion of the vessel	3,131.760
Net horse-power developed by the engines	3,871.259

THRUST OF THE SCREW

Thrust of the screw in pounds, calculated from the immediately above "horse-power expended in the propulsion of the vessel," and the speed of the vessel in feet per minute. This thrust is the net resistance of the vessel at the experimental speed and under the experimental conditions	60,799.43

Economy trial of the United States steam sloop *Wampanoag* under steam alone at sea along the coast of New Jersey, proceeding from and returning to the New York Navy Yard at the uniform speed of 11.5 geographical miles per hour, to determine the consumption of coal at that speed. Forward boilers only in use. Coal consumed with natural draught:—

Date of commencing the trial 2 p. m., Feb. 8, 1868

VESSEL

Average draught of water during trial, in feet	Forward	19.00
	Mean	19.33
	Aft	19.67
Greatest immersed transverse section, in square feet		654.80
Displacement, in tons of 2240 pounds		4,048.78
Immersed external surface of hull, including keel, in square feet		19,458.33

WIND AND SEA

Kind of wind	Strong breeze
Angle from ahead made by the wind with the vessel's keel, in degrees	112
State of the sea	Rough

TOTAL QUANTITIES

Duration of the trial, in consecutive hours	25
Number of geographical miles of 6086 feet steamed	287.5
Number of double strokes made by the pistons of the engines	31,980
Number of revolutions made by the screw	65,520
Number of pounds of coal consumed	101,080

COAL

Pounds of anthracite consumed per hour	4,043.2
Pounds of coal consumed per hour per square foot of grate surface	6.947
Fraction of a pound of coal consumed per hour per square foot of heating surface	0.223

TEMPERATURES IN FAHRENHEIT DEGREES

External atmosphere	38
Number of degrees of superheating given to the steam in the superheating boilers	30
Engine room	82
Forward fire-room	89
After fire-room (after boilers not used)	--
Injection or refrigerating water entering condenser	40
Injection or refrigerating water leaving condenser	58
Hot well or feed water	127

Speed of Vessel and Slip of Screw

Speed of the vessel per hour in geographical miles of 6086 feet	11.500
Axial speed of the screw per hour in geographical miles of 6086 feet	12.058
Slip of the screw per hour in geographical miles of 6086 feet	0.558
Slip of the screw in per centum of its axial speed	4.624

Engines

Number of double strokes made per minute by the pistons of the engines	21.320
Number of revolutions made per minute by the screw	43.680
Steam pressure in the steam pipe near the cylinders, in pounds per square inch above the atmosphere	20.47
Proportion of throttle valve open	0.08
Fraction of stroke of piston completed when the steam was cut off	0.667
Fraction of return stroke of piston completed when the steam was cushioned	0.735
Number of times the steam was expanded	1.453
Vacuum in condenser in inches of mercury	25.50
Barometer in inches of mercury	30.22
Pressure in condenser in pounds per square inch above zero	2.32

Steam Pressures in Cylinders, per Indicator

In pounds per square inch above zero at commencement of stroke of piston	30.30
In pounds per square inch above zero at point of cutting off the steam	19.00
In pounds per square inch above zero at end of stroke of piston	12 00
In pounds per square inch above zero at point where cushioning commenced	2.80
Mean back pressure against the piston, exclusive of the cushioning, in pounds per square inch above zero	3.30
Mean back pressure against the piston of the cushioning alone, in pounds per square inch above zero	4.50
Mean indicated pressure on pistons, in pounds per square inch	16.50
Mean net pressure on pistons, in pounds per square inch	15.00
Mean total pressure on pistons, in pounds per square inch	19.80

Power Developed

Indicated horse-power developed by the engines	1,332.040
Net horse-power developed by the engines	1,210.945
Total horse-power developed by the engines	1,598.448

Economy of the Power

Pounds of anthracite consumed per hour per indicated horse-power	3 035
Pounds of anthracite consumed per hour per net horse-power	3.339
Pounds of anthracite consumed per hour per total horse-power	2.530

Weight of Steam per Indicator

Pounds weight of steam drawn from the boilers per hour, calculated from the pressures in the cylinders at the point of cutting off the steam, and at the point at which the cushioning commenced. The steam supposed to be saturated	36,920.00

Distribution of the Net Horse-Power

Horse-power overcoming the friction of the load	90.821
Horse-power overcoming the friction of the water on the screw blades	87.677
Horse-power expended in the slip of the screw	47.740
Horse-power expended in the propulsion of the vessel	984.707
Net horse-power developed by the engines	1,210.945

Thrust of the Screw

Thrust of the screw in pounds, calculated from the immediately above "horse-power expended in the propulsion of the vessel," and the speed of the vessel in feet per minute. This thrust is the net resistance of the vessel at the experimental speed and under the experimental conditions	27,857.52

First preliminary trial of the United States screw sloop *Wampanoag* under steam alone at sea along the coast of New Jersey, proceeding from and returning to the New York Navy Yard. All boilers in use. Coal consumed with natural draught:—

Date of commencing the trial—4.30 p.m., Dec. 29, 1867

Vessel

Average draught of water during trial, in feet	Forward	18.083
	Mean	19.000
	Aft	19.917
Greatest immersed transverse section, in square feet		639.74
Displacement in tons of 2240 pounds		3,939.26
Immersed external surface of hull, including keel, in square feet		19,104.30

Wind and Sea

Kind of wind	Strong breeze
Angle from ahead made by the wind with the vessel's keel, in degrees	56
State of the sea	Rough

Total Quantities

Duration of the trial in consecutive hours	19½
Number of geographical miles of 6086 feet steamed	507
Number of double strokes made by the pistons of the engines	32,137
Number of revolutions made by the screw	65,880.85
Number of pounds of coal consumed	173.130

Coal

Pounds of mixed semi-bituminous coal and anthracite consumed per hour	8,878.462
Pounds of coal consumed per hour per square foot of grate surface	7.871
Fraction of a pound of coal consumed per hour per square foot of heating surface	0.290

Temperatures in Fahrenheit Degrees

External atmosphere	37
Number of degrees of superheating given to the steam in the superheating boilers	30
Engine room	70
Forward fire-room	80
After fire-room	84
Injection or refrigerating water entering condenser	43.4
Injection or refrigerating water leaving condenser	84.3
Hot well or feed water	160

Speed of Vessel and Slip of Screw

Speed of the vessel per hour in geographical miles of 6086 feet	13.000
Axial speed of the screw per hour in geographical miles of 6086 feet	15.411
Slip of the screw per hour in geographical miles of 6086 feet	2.411
Slip of the screw in per centum of its axial speed	15.643

Engines

Number of double strokes made per minute by the pistons of the engines	27.248
Number of revolutions made per minute by the screw	55.825

Steam pressure in the steam pipe near the cylinders, in pounds per square inch above the atmosphere	36.85
Proportion of throttle valve open	0.72
Fraction of stroke of piston completed when the steam was cut off	0.518
Fraction of return stroke of piston completed when the steam was cushioned	0.600
Number of times the steam was expanded	1.821
Vacuum in condenser, in inches of mercury	15.07
Barometer, in inches of mercury	30.53
Pressure in condenser, in ponnds per square inch above zero	7.394

STEAM PRESSURES IN CYLINDERS, PER INDICATOR

In pounds per square inch above zero at commencement of stroke of piston	47.39
In pounds per square inch above zero at point of cutting off the steam	43.00
In pounds per square inch above zero at end of stroke of piston	22.00
In pounds per square inch above zero at point where cushioning commenced	8.00
Mean back pressure against the piston, exclusive of the cushioning, in pounds per square inch above zero	9.00
Mean back pressure against the piston of the cushioning alone, in pounds per square inch above zero	12.00
Mean indicated pressure on pistons, in pounds per square inch	29.07
Mean net pressure on pistons, in pounds per square inch	27.57
Mean total pressure on pistons, in pounds per square inch above zero	38.07

POWER DEVELOPED

Indicated horses-power developed by the engines	2,999.340
Net horse-power developed by the engines	2,844.576
Total horse-power developed by the engines	3,927.928

ECONOMY OF THE POWER

Pounds of coal consumed per hour per indicated horse-power	2.960
Pounds of coal consumed per hour per net horse-power	3.121
Pounds of coal consumed per hour per total horse-power	2.260

WEIGHT OF STEAM PER INDICATOR

Pounds weight of steam drawn from the boilers per hour, calculated from the pressure in the cylinders at the point of cutting off the steam, and at the point at which the cushioning commenced. The steam is supposed to be saturated	73.3 8.272

DISTRIBUTION OF THE NET HORSE-POWER

Horse-power overcoming the friction of the load	213.343
Horse-power overcoming the friction of the water on the screw blades	183.032
Horse-power expended in the slip of the screw	382.972
Horse-power expended in the propulsion of the vessel	2,065.229
Net horse-power developed by the engines	2,844.576

THRUST OF THE SCREW

Thrust of the screw in pounds, calculated from the immediately above "horse-power expended in the propulsion of the vessel," and the speed of the vessel in feet per minute. This thrust is the net resistance of the vessel at the experimental speed and under the experimental conditions	51,684.24

NOTE.—The very inferior vacuum in the condenser during this experiment was caused by the fact that the "division plate" in the end of the condenser which received the injection water had not been secured in place by the contractors, so that a large portion of the injection water passed directly out of the condenser without passing through its tubes. Nevertheless, the compensating advantages of the resulting high temperature of the feed water (160°), and of the diminished cylinder condensation due to the resulting high temperature of the back pressure against the pistons, were so great that the cost of the power in fuel was not disadvantageously affected,—a most remarkable experimental fact.

Second preliminary trial of the United States screw sloop *Wampanoag* under steam alone at sea along the coast of New Jersey, proceeding from and returning to the New York Navy Yard. All boilers in use. Coal consumed with natural draught:—

Date of commencing the trial--4.30 p.m., Jan. 2, 1868

VESSEL

Average draught of water during trial, in feet	Forward	17.67
	Mean	18.58
	Aft	19.50
Greatest immersed transverse section, in square feet		620.92
Displacement, in tons of 2240 pounds		3,802.36
Immersed external surface of hull, including keel, in square feet		18,812.60

WIND AND SEA

Kind of wind	Light airs
Angle from ahead made by the wind with the vessel's keel, in degrees	140
State of the sea	Moderate

TOTAL QUANTITIES

Duration of the trial, in consecutive hours	9
Number of geographical miles of 6086 feet steamed	273
Number of double strokes made by the pistons of the engines	16,490
Number of revolutions made by the screw	33,804.5
Number of pounds of coal consumed	105,120

COAL

Pounds of mixed semi-bituminous coal and anthracite consumed per hour	11,680
Pounds of coal consumed per hour per square foot of grate surface	10,355
Fraction of a pound of coal consumed per hour per square foot of heating surface	0.382

TEMPERATURES IN FAHRENHEIT DEGREES

External atmosphere	43.5
Number of degrees of superheating given to the steam in the superheating boilers	30
Engine room	82
Forward fire-room	87.5
After fire-room	89
Injection or refrigerating water entering condenser	41.6
Injection or refrigerating water leaving condenser	68.2
Hot well or feed water	155

SPEED OF VESSEL AND SLIP OF SCREW

Speed of vessel per hour in geographical miles of 6086 feet	15.167
Axial speed of the screw per hour in geographical miles of 6086 feet	17.271
Slip of the screw per hour in geographical miles of 6086 feet	2.104
Slip of the screw in per centum of its axial speed	12.180

ENGINES

Number of double strokes made per minute by the pistons of the engines	30.537
Number of revolutions made per minute by the screw	62.564

Steam pressure in the steam pipe near the cylinders, in pounds per square inch above the atmosphere	39.30
Proportion of throttle valve open	0.88
Fraction of stroke of piston completed when the steam was cut off	0.547
Fraction of return stroke of piston completed when the steam was cushioned	0.600
Number of times the steam was expanded	1.735
Vacuum in condenser, in inches of mercury	16.6
Barometer, in inches of mercury	29.94
Pressure in condenser, in pounds per square inch above zero	6.545

STEAM PRESSURE IN CYLINDERS, PER INDICATOR

In pounds per square inch above zero at commencement of stroke of piston	50.91
In pounds per square inch above zero at point of cutting off the steam	47.00
In pounds per square inch above zero at end of stroke of piston	25.15
In pounds per square inch above zero at point where cushioning commenced	7.00
Mean back pressure against the piston, exclusive of the cushioning, in pounds per square inch above zero	8.00
Mean back pressure against the piston of the cushioning alone, in pounds per square inch above zero	11.25
Mean indicated pressure on pistons, in pounds per square inch	33.37
Mean net pressure on pistons, in pounds per square inch	31.87
Mean total pressure on pistons, in pounds per square inch above zero	41.37

POWER DEVELOPED

Indicated horse-power developed by the engines	3,858.590
Net horse-power developed by the engines	3,685.144
Total horse-power developed by the engines	4,783.634

ECONOMY OF THE POWER

Pounds of coal consumed per hour, per indicated horse-power	3.027
Pounds of coal consumed per hour, per net horse-power	3.169
Pounds of coal consumed per hour, per total horse-power	2.442

WEIGHT OF STEAM PER INDICATOR

Pounds weight of steam drawn from the boilers per hour, calculated from the pressures in the cylinders at the point of cutting off the steam, and at the point at which the cushioning commenced. The steam is supposed to be saturated	98,011.49

DISTRIBUTION OF THE NET HORSE-POWER

Horse-power overcoming the friction of the load	276.386
Horse-power overcoming the friction of the water on the screw blades	257.382
Horse-power expended in the slip of the screw	383.838
Horse-power expended in the propulsion of the vessel	2,767.538
Net-horse-power developed by the engines	3,685.144

THRUST OF THE SCREW

Thrust of the screw in pounds, calculated from the immediately above "horse-power expended in the propulsion of the vessel," and the speed of the vessel in feet per minute. This thrust is the net resistance of the vessel at the experimental speed and under the experimental conditions	59,364.55

NOTE.—The very inferior vacuum in the condenser during this experiment was caused by the fact that the "division plate" in the end of the condenser which received the injection water had not been secured in place by the contractors, so that a large portion of the injection water passed directly out of the condenser without passing through its tubes. Nevertheless, the compensating advantages of the resulting high temperature of the feed water (155°), and of the diminished cylinder condensation due to the resulting high temperature of the back pressure against the pistons, were so great that the cost of the power in fuel was not disadvantageously affected,—a most remarkable experimental fact.

DOCK TRIAL OF THE MACHINERY OF THE UNITED STATES STEAM SLOOP "WAMPANOAG"

The following data were obtained while the engines of the *Wampanoag* were working with the vessel secured alongside the dock of the New York Navy Yard. The depth of water was such that the lower edge of the keel was only about 2 feet above the bottom when the engines were in operation. The screw was well covered with water when the machinery was not working, and still more covered when it was working. The vessel "squatted" considerably when the machinery was in operation.

Number of double indicator diagrams taken from the cylinders	1,007	222
Number of double strokes made per minute by the pistons of the engines	10.96	14.21
Number of revolutions made per minute by the screw	22.468	29.130
Indicated pressure on the pistons, in pounds per square inch	12.34	17.42
Net pressure on the pistons, in pounds per square inch	10.84	15.92
Ratio of the net pressures on the pistons	1.000	1.469
Ratio of the squares of the number of revolutions made by the screw per minute	1.000	1.681
Indicated horse-power developed by the engines	512.120	937.321
Net horse-power developed by the engines	449.869	856.610

DISTRIBUTION OF THE NET HORSE-POWER.

Horse-power overcoming the friction of the load	33.740	64.246
Horse-power overcoming the friction of the water on the screw blades	11.919	25.960
Horse-power expended in the displacement of water by the screw	404.210	766.404
Net horse-power developed by the engines	449.869	856.610

THRUST OF THE SCREW

Thrust of the screw in pounds, calculated from the immediately above "horse-power expended in the displacement of water by the screw," and the axial speed of the screw in feet per minute (306.88 and 397.88 feet)	43,466.27	63,565.23

"The ratio of the squares of the number of revolutions made by the

screw per minute" (1.000 and 1.681), ought, abstractly, to have been the same as "the ratio of the net pressures on the piston" (1.000 and 1.469), and would have been the same practically, but that, with the increase in the rotary speed of the screw from 22.486 to 29.130 revolutions per minute, the water could not reach the screw in the same proportional weight per unit of time at the greater number of revolutions of the screw that it did at the lesser number. This was owing to the small depth of water between the lower edge of the keel and the ground. Almost the whole water supply to the screw came from forward to aft beneath the bottom of the hull, sinking from the stem to the greatest immersed transverse section, and rising from that section until it met the normal water surface. No sensible quantity of water came in sidewise to the screw. At a certain distance abaft the screw there was quite a wave or head of water above the general water level, due to the *vis viva* of the water rising from the horizontal plane of the lower edge of the rabbet of the keel of the vessel to the surface of the water, which *vis viva* carried the uprising water above the general water level. From the crest of this wave there was a surface current forwards towards the screw due to the inclination of the water surface in that direction, and from the crest of this wave there was a surface current backwards from the screw due to the inclination of the water surface in that direction. The water thrown backwards by the screw was in a direction at right angles to the surface of its blades. There was no surface current along the sides of the vessel from forward to aft; but, on the contrary, there was a very slight reverse surface current extending from the sternpost to about one-third the length of the vessel.

The action of the screw and of the water current beneath the bottom of the vessel stirred up the mud from the ground, some of which entered the condenser with the injection water during the long trials of the machinery with the vessel secured to the dock, and, by coating the condenser tubes with mud, impaired their heat conducting power so that the vacuum during the succeeding trials at sea was less than it otherwise would have been; but this fact did not affect the fuel economy within the experimental limits, as the resulting increased temperature of the feed-water and the decreased cylinder condensation were sufficient compensations. The lower vacuum was not due to air leaks, but to non-liquefaction of the exhaust steam below a certain temperature.

Every steam engine, and every regimen of steam, has its own peculiar temperature of feed-water which gives the maximum economy of fuel, and which can only be experimentally ascertained. No experiments have been made to determine, in given different cases, this temperature. Probably it admits of wide variation without affecting the fuel economy, the gains sensibly equilibrating the resulting losses. The higher the feed-water temperature, the less tube surface is required in the condenser; but, then, the higher the feed-water temperature, the larger must be the capacity of the cylinder for developing equal powers, other things equal, owing to the increased back pressure against the piston with higher temperature of the condenser. The higher temperature of the feed-water increases the economic vaporisation by the boiler in a higher degree than is due, numerically, to the increased temperature of that water, because the heating surface of the boiler having, in equal time, to transmit less heat, will, necessarily, utilise more of the heat in the gases of combustion than it would do with feed-water of lower temperature.

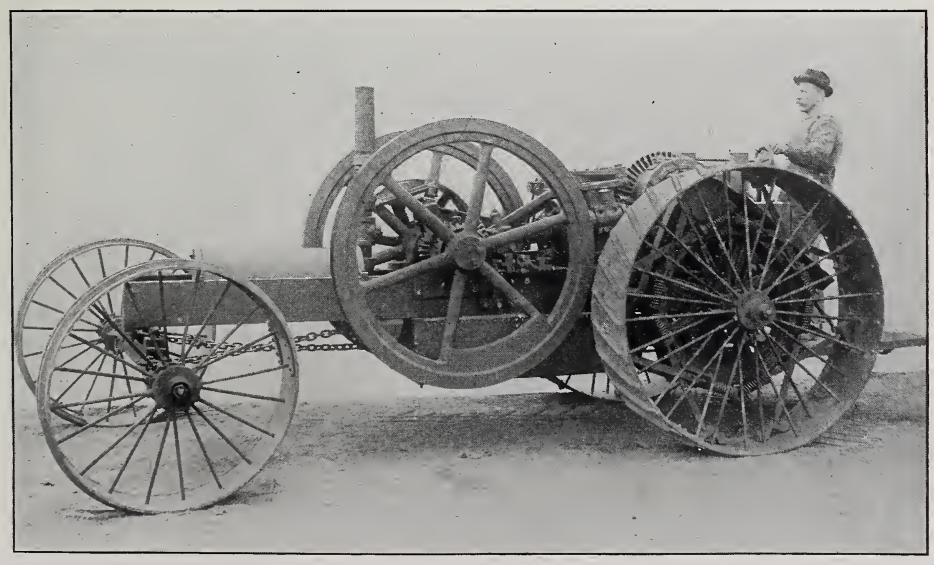
Further, with the same engine, for the production of a given power with equal reciprocating speed of piston, the boiler pressure must be carried higher, the higher the back pressure against the piston, and there is a distinct and measurable economic gain due to the greater dynamic effect of a given weight of steam of higher pressure over the same weight of steam of lower pressure, after allowing for the greater total heat of the former.

GAS ENGINE FUELS, TYPES, AND USES

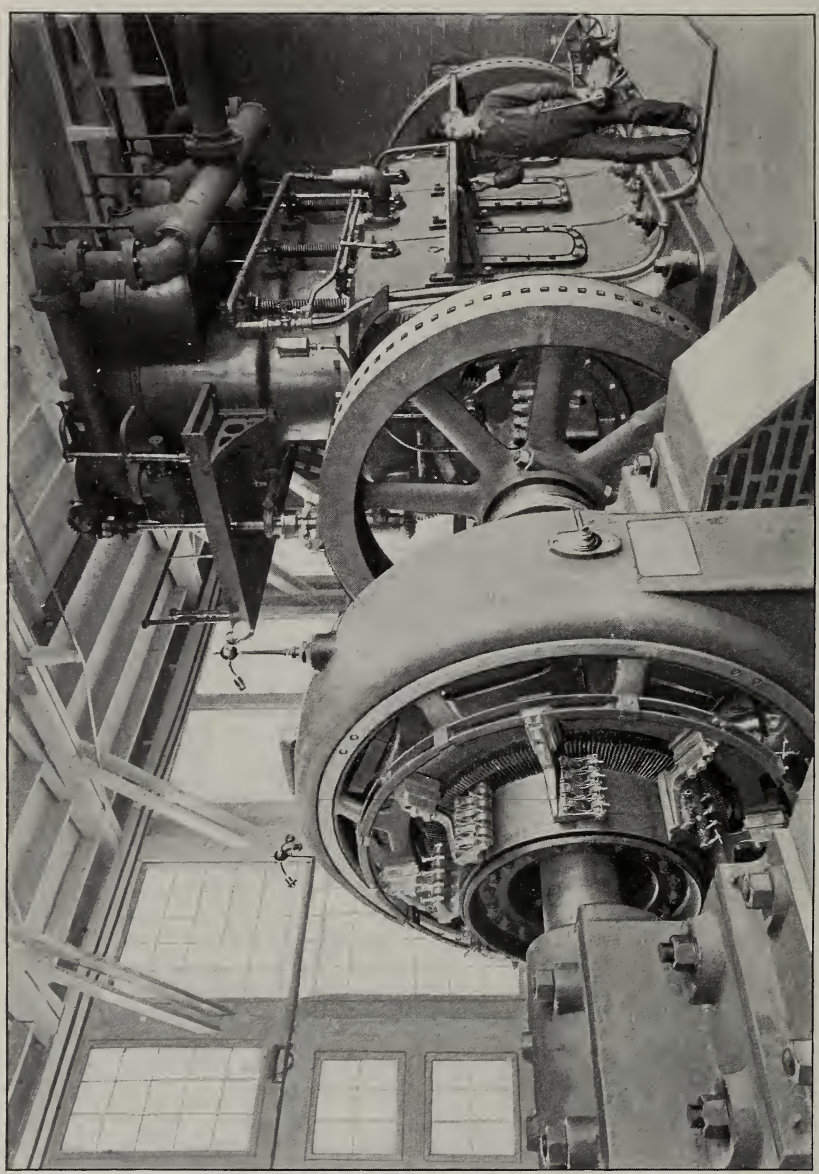
By Professor C. V. Kerr

ABOUT 1680 the Dutch philosopher Huyghens, by igniting a charge of gunpowder to drive a piston upward in a cylinder by the expansive force of the hot gases of combustion, created a machine, now developed into the gas engine, which antedated the steam engine so far as it used a cylinder and piston to utilise the expansive force of steam. At that time it was unknown that nature had been storing up, deep in the earth, under great pressure, a fuel far better adapted to the peaceful development of power than gunpowder. Natural gas in its richness, cheapness, and pressure is the ideal fuel for the gas engine. The exact source and process of formation can only be inferred; probably it is the decomposition of organic matter under heat and pressure. The result is a mixture of gases consisting of perhaps 2 per cent. of free hydrogen, 93 per cent. of marsh gas, with a remainder made up of nitrogen, oxygen, oxides of carbon and a little hydrogen sulphide. In round numbers, its heating power is measured by a thousand thermal units per cubic foot, each equivalent to lifting 778 pounds one foot high. The best gas engines have yielded a brake-horse-power on nine cubic feet of such gas,—a heat efficiency of 28 per cent. Steam engines are considered to do very well at half of that.

A dozen years ago natural gas was sold in the United States, at Pittsburgh, by meter for domestic purposes at ten cents per thousand cubic feet, and for mill use at as low a rate as five cents. A gas engine giving a brake-horse-power on ten cubic feet of such gas per hour would use half a cent's worth of fuel for each working day of ten hours; or for a year of 3000 hours the cost per brake-horse-power would be $1.50. At Chi-



AN OTTO OIL TRACTION ENGINE



A 650 H. P. GAS ENGINE CONNECTED DIRECT TO AN ELECTRIC GENERATOR. BUILT BY, AND IN OPERATION AT THE SHOPS OF, THE WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY PITTSBURGH

cago, where natural gas for heating and power purposes is sold by meter at fifty cents per thousand cubic feet, the cost would be five cents per day, or fifteen dollars per year. A good steam engine, giving a brake-horse-power on two pounds of coal per hour, would cost two cents per day, or six dollars per year, for fuel. The total cost of power includes many other items than fuel, but their discussion is most effective when connected with competitive designs for some proposed power plant.

The pressure under which natural gas has been found stored up by nature varies from 320 pounds per square inch in the Indiana field to 450 at Findlay, Ohio, and a maximum of 1020 at Castle Shannon, Pennsylvania. The escape of the gas from the wells at a greater rate than it is formed by nature's slow process has reduced this pressure so much that pumps are used to maintain the supply and pressure. Thus the gas in the Indiana field, intended for use in Chicago, is compressed to 300 pounds per square inch. But at the city, 125 miles away, the pressure is measured by a column of water two or three inches in height, corresponding to an ounce and a half per square inch. Since the difference in pressure is almost entirely due to friction in the pipe line, a limit to the economical distribution of gas for power purposes is indicated. During the days, however, when gas and pressure were both abundant, the gas as it came from the wells was often used, as compressed air would be, to develop power by its expansive force.

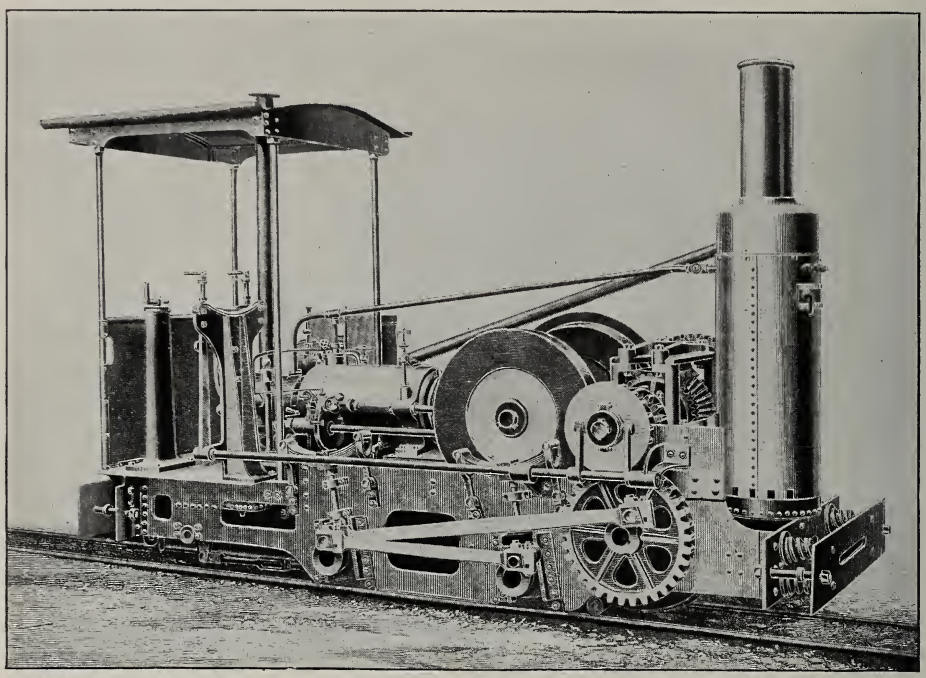
When the supply of natural gas in the localities where it is now known finally fails, as it doubtless will, what is to take its place? The attention naturally turns to some form of artificial gas. It is now more than a century since Murdoch, the talented associate of Boulton and Watt, first proved the practicability of using gas made from coal for lighting the famous engine works at Soho. It is difficult now, with our knowledge of the composition of gases and of the theory of combustion, to realise the mystery surrounding the use of gas for lighting a century ago. It is said that even members of the British Parliament who saw the bright yellow flame issuing from the conducting pipes expressed surprise on finding, after cautious investigation, that the pipes were cold.

The commercial use of gas for lighting gave an impetus to gas engine invention. The French engineer, Lebon, in 1801 proposed to use coal-gas and air in proper mixture, introduced alternately on each side of a piston in a double-acting engine and ignited by an electric spark. But the first working gas engine, as has often been told, was brought out in 1860 by Lenoir. It closely resembled a double-acting steam engine in construction. It worked quietly, and could be quickly started or stopped. Nothing could apparently be simpler or better suited to drive machinery of all kinds. It was claimed that its use made gas cheaper than steam.

Lenoir's friends confidently affirmed that the reign of steam was over and that it would be at once replaced by gas. Consequently, when exact, but unsympathetic tests showed the consumption of gas to be more than three times as much as claimed, the new idol suffered a heart-breaking fall from its pedestal.

In the meantime, artificial gas was making its way into favour for lighting purposes. The advent, a score of years ago, of the electric incandescent bulb and of the arc lamp, was made the occasion of a prophecy that the gas light would soon be a thing of the past. The stimulus of competition, however, induced a closer study of the chemistry of gas-making and of the disposal of the by-products, so that in some cases these former nuisances pay for all the fuel used.

In 1897 a test was made at Stevens Institute of Technology on a 20 horse-power gas engine coupled by a friction clutch to a dynamo, which is of interest from the fact that more light was shown to be obtained per cubic foot of gas when burned in the engine than if used direct in the ordinary burner. Recently it has been claimed that if a gas company were to replace the present gas



AN OIL LOCOMOTIVE, BUILT FOR WOOLWICH ARSENAL BY MESSRS. R. HORNSBY & SONS, LTD., GRANTHAM. IT WAS NECESSARY IN THIS CASE TO HAVE AN ENGINE THAT WOULD NOT GIVE OFF ANY SPARKS OR FIRE WHILE RUNNING

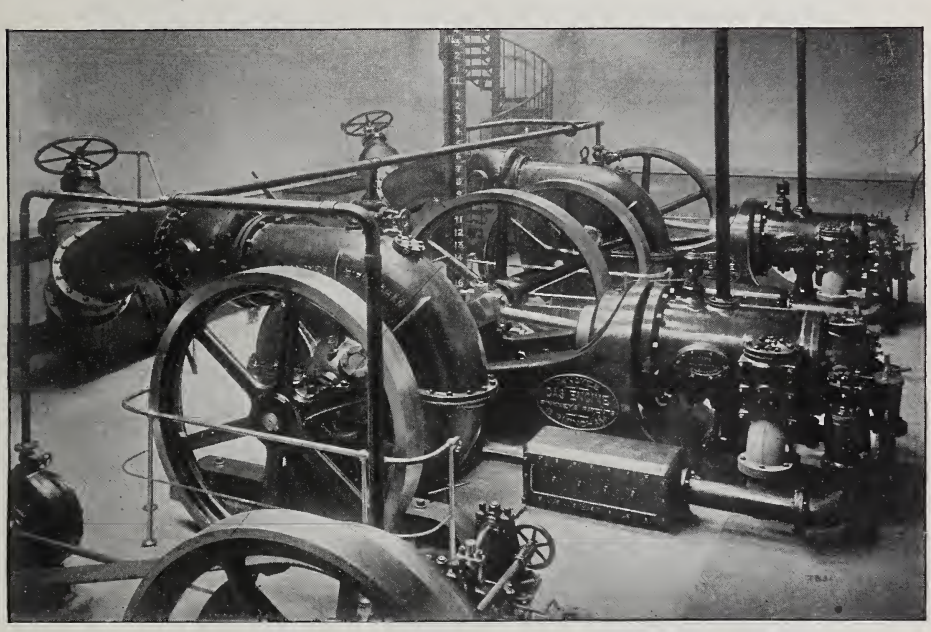
light by an equal amount of electric lights obtained from gas-driven engines, it would have left, for sale, over 60 per cent. of its present gas output. That is the way to convert a competitor into a co-labourer.

In the meantime, it is also claimed for the incandescent gas mantle that three times as much light can be obtained by its use as by the ordinary lava tips. These mantles are fragile, but so are the filaments of the electric lamp, and the relative cost of renewals is an uncertain quantity. For public lighting the electric lamp and for private lighting the incandescent mantle may prevail. In either case the gas companies will get the benefit, and, through them, in the larger sense, the oft-times unappreciative public. In spite of the dire prediction referred to, these companies still pay dividends and make more gas than ever. In fact, as a young but successful friend in the business remarks, "gas making is just in its infancy."

If natural gas is not available, will it pay to use illuminating gas for power? Suppose that such gas, costing one dollar per 1000 cubic feet, each cubic foot containing 650 thermal units, is used in a gas engine which develops a brake-horse-power on 20 cubic feet per hour, 200 feet per day, or 60,000 feet per year of 3000 working hours. The annual cost per horse-power will be $60 for fuel only. Suppose that coal, costing $2 per ton, develops at the steam engine a brake-horse-power on three pounds per hour, 30 pounds per day, or 9000 pounds per year. The annual cost per brake-horse-power will be only $9. As the cost of the gas engine per brake-horse-power will be more than that of the steam plant, and as the effect in annual cost must be sought in smaller cost of attendance, repairs and depreciation, it is evident that the use of illuminating gas for power must be limited.

For the small plants, to which the use of illuminating gas is usually re-

stricted, gasoline, costing perhaps twelve cents per gallon, may be used. A brake-horse-power may be obtained from one pint per hour, and at ten hours per day, or 3000 per year, this will amount to $45, on the basis of a cent and a half per pint. For small powers, and especially when infrequently used, the advantages of convenience of operation, small cost of attendance and safety outweigh the greater fuel cost and determine the choice of a gas or gasoline engine.



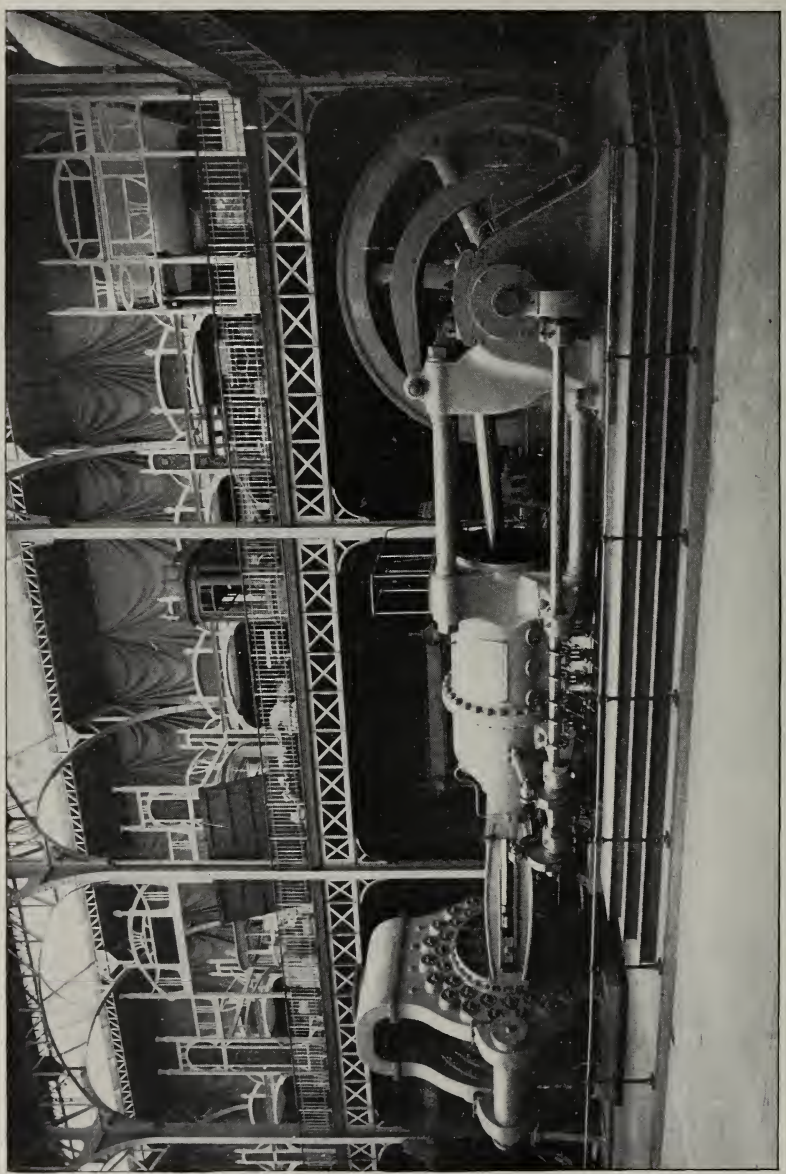
CENTRIFUGAL DOCK PUMPS FOR THE RIVER WEAR COMMISSIONERS, DRIVEN BY GAS ENGINES, BUILT BY MESSRS. TANGYES, LTD., BIRMINGHAM, ENGLAND

In the larger power plants where natural gas is not available, some other fuel must be sought than illuminating gas or gasoline. Tests recently made at Stevens Institute on a 20 horse-power Diesel motor prove it capable of using a fuel oil costing 2 cents per gallon, so that a brake-horse-power-hour would cost 0.2 cents, or 2 cents per day of ten hours, or $6 per year of 3000 hours. This equals the fuel cost of the best steam engines of large size.

In the last few years attention has been drawn to the resources for gas engine power represented by the gases from blast furnaces. At the works of the Glasgow Iron Company, at Wishaw, Scotland, the furnaces are supplied with a plant for the recovery of residuals. An exhaust fan draws gas from a main leading from the residual plant, passes it through a dust filter, and stores it in a holder. Thence it passes to a 20 horse-power gas engine belted to a direct-current dynamo. An electrical horse-power has been developed on 1.25 to 1.50 pounds of coal fed to the furnace. The composition of the gas is as follows:—

Carbon monoxide, CO	26.78	per cent.
Hydrogen, H	5 20	"
Marsh gas, CH_4	3.57	"
Carbon dioxide, CO_2	7.38	"
Nitrogen, N	57.07	"
	100 00	"

The heating power is about ninety-eight thermal units. Both in Great Britain and France plans are in effect or being carried out for the similar use of blast furnace gases. At Seraing, in Belgium, an 8 horse-power gas engine has run four months continuously without cleaning, using waste gas from a



A GAS ENGINE-DRIVEN BLOWING ENGINE SHOWN AT THE PARIS EXPOSITION BY MESSRS. JOHN COCKERILL, LTD., SERAING, BELGIUM. AT THE SERAING WORKS THIS ENGINE IS WORKED WITH BLAST FURNACE GAS

blast furnace. Dust does not seem to be a serious obstacle.

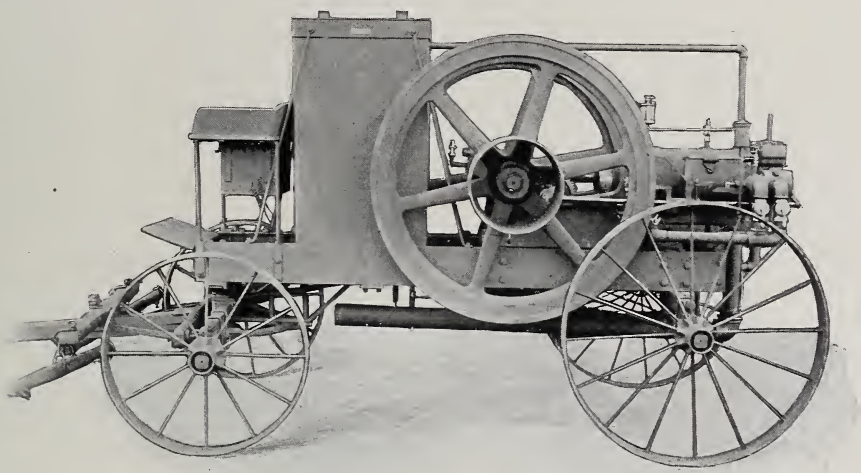
A part of the enormous volume of gas obtained annually from blast furnaces has been used for raising steam in the ordinary boiler. Data from tests show, however, that such gas is inefficient under a steam boiler, while in a gas engine its efficiency nearly or quite equals that of illuminating gas. The combustibles in blast furnace gas are hydrogen, marsh gas and carbon monoxide, all of which burn with a blue flame. Consequently it has a low radiating power during combustion, which is an advantage in the gas engine, since less heat will be carried away by the jacket water; but a fuel of low radiating power is at a disadvantage under a boiler.

If the blast furnace gases which pollute and poison the air in the vicinity of the furnaces could be utilised in gas engines driving dynamos generating electricity, to be distributed within a radius of 30 to 50 miles, they might become a source of comfort and not of harm to the community.

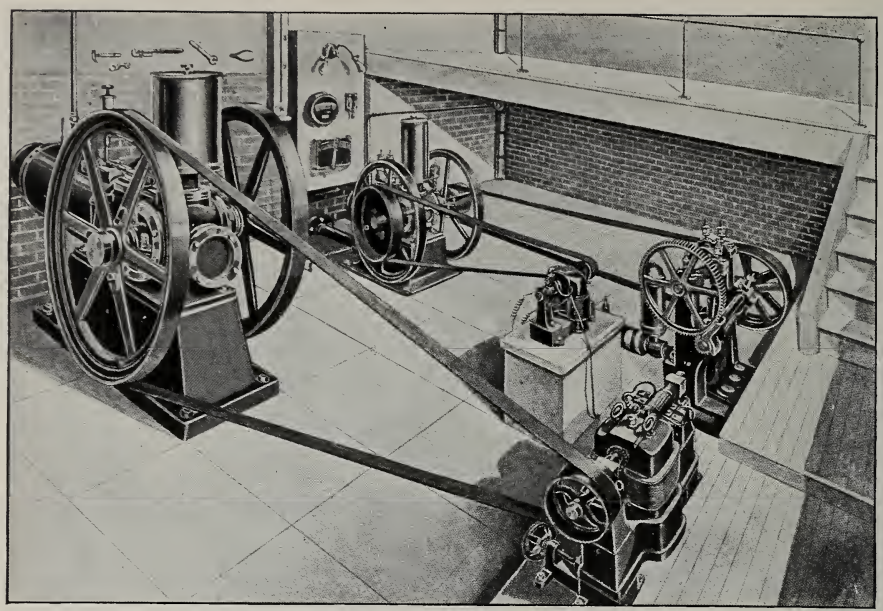
But unless we can acquire control of very much higher potentials than are now practicable, the distribution of current about the vicinity of blast furnaces must remain limited to a relatively small area. And the utilisation of the immense volumes of waste gases in restricted localities cannot be hoped for, because furnaces have been located with reference to the production of pig iron and not to the generation and use of electricity.

With the limitation of supply on natural gas, of cost on illuminating gas, and of distribution on furnace gas, a lively interest is at once aroused by the claim that "the cheapest artificial fuel gas per unit of heat is common producer gas." The process of manufacture consists primarily in blowing through a deep incandescent bed of anthracite or bituminous coal, air carrying as much steam as the producer will permit and maintain good incandescence. The oxygen of the air forms finally carbon monoxide, while the steam breaks up, in the presence of hot carbon, into hydrogen and oxygen with various reactions with the complex constituents of the coal, so that the combustibles in the resulting producer gas are carbon monoxide, free hydrogen and marsh gas. Leaving the producer proper, the gases pass through an economiser, scrubber and purifier to the gas holder, where it is ready for use in the engine.

Such gas is the lowest in heating



A PORTABLE GASOLINE ENGINE, MADE BY THE PIERCE ENGINE CO., RACINE, WIS., U. S. A.



AN ELECTRIC LIGHT AND PUMPING PLANT, DRIVEN BY MIETZ & WEISS GAS ENGINES, BUILT BY A. MIETZ, NEW YORK

power per cubic foot of all artificial gases, but it shows a high efficiency in the gas engine. Thus, Professor H. W. Spangler reported to the *Journal* of the Franklin Institute for May, 1893, a test of a producer plant furnishing gas to a 100 horse-power gas engine which developed a brake-horse power on 1.3 pounds of coal per hour when the mechanical efficiency was only 72 per cent.

As an indication of the possibilities of producer gas, attention should be called to the gas producer plant put in by Messrs. R. D. Wood & Co., of Philadelphia, for the Erie Railroad at Jersey City, New Jersey. The plant comprises two gas producers with coal elevator and automatic feed. The gases are passed through a superheater and economiser, scrubber and purifier to a holder which contains a ten-minute supply for the engines. Two 90 and two 45 horse-power gas engines are in use at the plant, while gas is also piped about twelve hundred feet away to gas engines driving coal and ash-handling apparatus. One man attends the producer and fires the boiler used to supply steam to the producer. Another man and helper look after the engines and electrical apparatus. The first cost and labour charge of such a plant are said to be about equal to that of first-class steam engines and boilers, with much less wear and tear.

Two analyses of the gas produced made on different days show the following composition:—

	(1)	(2)
Carbon monoxide, CO	17.2	19.4
Hydrogen, H	18.3	16.6
Marsh gas, CH_4	2.4	2 8
Oxygen, O	0.4	0.8
Carbon dioxide, CO_2	8.6	8.2
Nitrogen, N	53.1	52 2

The calorific power of the gas ranged from 136 to 143 thermal units per cubic foot, and 84.7 cubic feet of gas were delivered per pound of coal, or about 12,100 thermal units. The gas engines using this producer gas developed an indicated horse-power on 1.03 pounds of coal, or perhaps 1.25 pounds per brake-horse-power.

The most satisfactory fuel for use in a gas producer is coal or coke. The necessity for fixing the condensible hydro-carbons from soft coal is the chief obstacle. Still a 100 horse-power gas engine has been run on producer

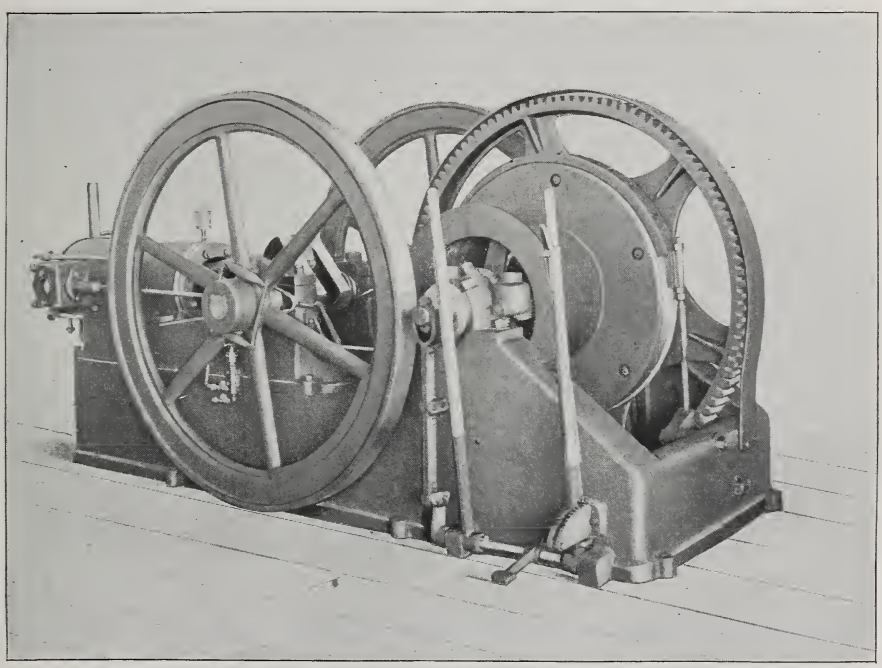
gas from soft coal with a coal expenditure of two pounds per brake-horse-power-hour.

But so long as the producer is confined to hard coal or coke it is limited either by locality or cost. To grasp its opportunity fully the producer must also handle satisfactorily the grades of soft coal usually supplied to steam boiler plants. Then the gas engine can enter with the prospect of success into competition with the steam engine in its most lucrative field, that of furnishing power for electric lighting and railway work.

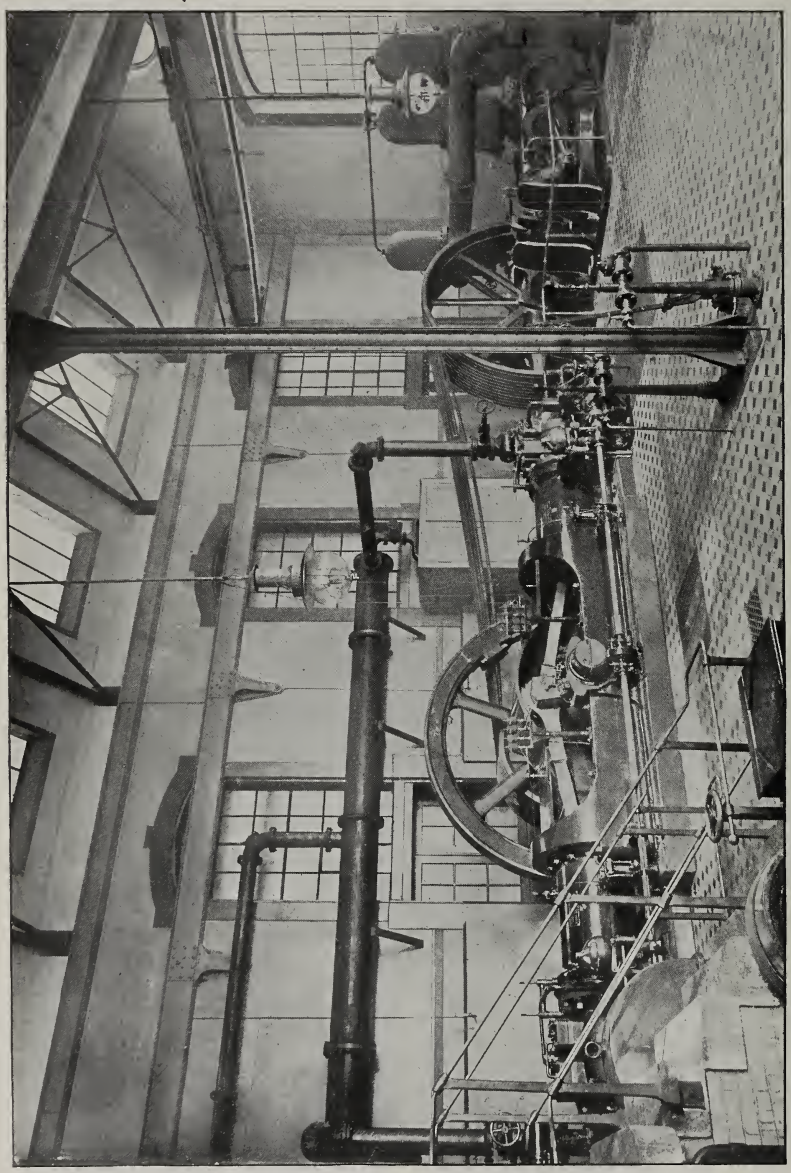
By far the greatest number of gas engines now in use follow what is generally known as the Otto cycle, in which the events during four strokes of a single acting cylinder are (1) expansion, (2) exhaust, (3) suction, (4) compression. A few engines, designed for service where regularity of rotative speed is of more importance than high efficiency, effect the expansion and exhaust during the outstroke and the compression during the return stroke, thus converting the four-cycle into a two-cycle engine.

Again, most of the engines using the Otto cycle govern speed on the "hit and miss" principle, by which the engine uses an explosive mixture of constant quality and volume, but regulates the admissions of gas to suit the load. The engine thus receives an impulse at full load for each two revolutions, and at less frequent intervals for light loads. The plan may maintain the heat efficiency at light loads, but certainly not the regularity of rotation. In electric lighting, the steadiness is even more important than efficiency. To secure, to the highest degree possible, both of these qualities, the designers of the Westinghouse gas engine employ an explosive mixture of constant quality, but vary the quantity admitted to the cylinder to suit the load.

Now, it has been found that the higher



A GASOLINE ENGINE AND GEARED HOIST, MADE BY MESSRS. FAIRBANKS, MORSE & CO., CHICAGO, U. S. A.



THE WATER WORKS AT BASEL, SWITZERLAND, DRIVEN BY GAS ENGINES, BUILT BY THE GASMOTOREN FABRIK DEUTZ, KÖLN, GERMANY

the pressure of compression in the Otto cycle, the higher the efficiency. Thus, compression to 38, 66.6, 82.5, and 95 pounds gauge pressure were accompanied by heat efficiencies of 17, 21, 25, and 30 per cent. But with a constant explosive mixture the heat of compression, added to the heat of explosion, soon sets a limiting initial pressure beyond which it does not pay to go. This has been very well shown by tests where, with successive compression pressures of 24, 61, 105, and 112 pounds, the maximum pressures of explosion were 27, 117, 233, and 347 pounds. The maximum pressure increases much more rapidly than the compression, and it is a question how much further in quest of efficiency it will be safe to go. The tendency is evidently toward a detonation of the explosive mixture.

In the Diesel motor, in which oil fuel is burned practically at constant pressure, this is determined entirely by the compression pressure. Hence the engine runs quietly and steadily under pressures of 500 to 600 pounds with a corresponding heat efficiency. Herein lies a great advantage of burning the fuel at constant pressure instead of at constant volume. As yet a successful engine burning gas at constant pressure has not been offered. The method was tried nearly thirty years ago in the Brayton gas engine, but the design failed on account of back-firing into the reservoir.

A complete catalogue of the uses to which gas engines may be successfully put will not be desirable here. One of the neatest and most serviceable outfits is the gas or gasoline engine of the smaller powers, direct-connected to a dynamo producing current for light or power. The high efficiency of the small engine, its safety, convenience and durability make it an ideal prime mover for small factories, residences and schools; and it is claimed for one of these combinations that a regulation equal to 1 per cent. is being secured in every-day service, and that ten lights of 16 candle-power each can be produced for a cost of one cent per hour,—about one-tenth of the price regularly charged by city central plants. The combined engine and air compressor is also being used to supply compressed air for its almost endless variety of uses.

Gas or gasoline engines drive launches on lake and river, pumps to raise water for villages and towns, hoists for coal mines, separators for threshing wheat, mills for grinding feed, elevators, wood and iron working machinery, ice machines, and, lastly, the ubiquitous automobile.

The future, dim, though near, must be allowed to say what type of gas engine will be preferred and to what use it shall be put. For all we admire the gas engine and hasten its progress with good wishes, it must not be forgotten that the turbine is ready to save the millions of horse-power now running to waste at the world's waterfalls whenever the public is ready to consider that such waste is a sin; nor that the steam engine can make excellent use of the unmeasured power stored in coal. Not sentiment, but money, will be the final arbiter in the battle of the prime movers.

CASTINGS FOR HYDRAULIC SERVICE

By R. P. Cunningham

THE mixing of iron for castings used on hydraulic work, or for any casting that is required to stand great liquid pressure, has never received proper attention by the average foundryman. It is a common occurrence in shops where hydraulic work is cast to have trouble with leaky castings. This is not only aggravating, but expensive as well, as the machine work done on the casting often amounts to several times the cost of the casting originally. To have the cost of the casting and labour charged back to the foundry is something that the foreman does not relish, and very often he is not to blame for the defective castings, as he may have done everything he could, and the only blame that could be laid on him is that he should have known his iron. If he had, the result would have been different. As it was, he tried to do the best he could with what he had, and his failure should be divided with those who compelled him to use iron unfit for the work required.

Dealing with this subject recently before the American Foundrymen's Association, the writer pointed out that even in the best-managed foundries the metal sometimes goes astray with attending unpleasant experiences. Often large sums are lost; the foreman is called into the office and is shown letters from the firm's best customers, complaining about the castings; he is at a loss to understand the cause; his reputation is at stake. Upon investigation he is more confused than ever. Everything was conducted as usual; every rule he laid down had been followed; and yet these breaks occur, and are difficult to explain. Every one admits that some thing is wrong, but how are we to locate the trouble? The answer is easy. Chemistry will afford relief. If you should want a good piece of woodwork done, would you insist on using an inferior wood, or would you allow the woodworker to select the wood best suited for the work? If you wanted a special tool made, would you insist on your blacksmith using a cheap steel, or would you allow him the privilege of using his own judgment, and select the steel best adapted for this particular piece of work? The foundryman should know his iron as the woodworker knows his wood or the blacksmith knows his steel. He should be able to tell at once the kind of iron required for any kind of work. This information can be easily obtained by an analysis of the irons.

Taking the six principal elements found in pig iron, namely, silicon, sulphur, phosphorus, manganese, combined carbon and graphitic carbon, let us see what effect these will have upon the castings!

Carbon has more influence on the physical characteristics of cast iron than any other; and within certain limits the influences of the various other elements are exerted not on the iron itself, but on the carbon. According to Fresenius, four forms of carbon are present in cast iron, but only two are well known, *i.e.*, graphitic carbon and combined carbon. In the total carbons in any one iron there is not a great variation; but the effects of the relative amounts of the two on the strength and appearance of the iron are enormous. The higher the carbon, the weaker the iron. Graphitic carbon renders iron soft, but low in tensile strength. This arises from the

fact that it is simply an inter-molecular and not a true chemical combination, as is combined carbon. Iron high in combined carbon will have greater strength. The remelting will change graphitic carbon into combined carbon, and increase the strength and density of the iron.

Silicon in iron is better known than any other element. Its effect on foundry iron is that of a softener, *i.e.*, it turns carbon into the graphitic state, owing to its great power over carbon, from which it is impossible to separate it. It is considered that anything above two per cent. weakens the iron.

Sulphur turns graphitic carbon into the combined state, and makes the iron closer grained, but, in a casting with uneven thickness, is liable to crack it. This is overcome by melting the iron hotter, as the hotter the iron, the lower the sulphur and graphitic carbon. A small amount of sulphur is not objectionable in iron used in casting hydraulic work, as an iron to show great strength and density should contain from 0.03 to 0.05 per cent. It should not be forgotten that coke contains a large amount of sulphur, and iron readily takes it up —and often the iron is condemned when the fault is with the coke. Therefore, one can readily see that it is as necessary to know the analysis of the coke as of the iron. It is a well-known fact that some of the best coke contains 0.50 per cent. of sulphur, and some even more. For this reason the sulphur should be as low as possible in the iron.

Phosphorus also has a tendency to convert graphitic carbon into the combined state, but owing to the greater efficiency in this respect of silicon and sulphur its influence is not so marked. On account of fluidity and a tendency to overcome shrinkage, it is valuable in iron used in hydraulic work, as in most cases with this class of work there are a large number of cores and there are apt to be cold shuts unless the iron is very fluid. Another fact in this work is that the thickness is very uneven and the metal is liable to be porous unless it is fairly high in phosphorus, say from 0.50 to 0.80 per cent.; but on light work it may run as high as 1 per cent.

Manganese, like sulphur, has a tendency to make iron harder and denser; but as most irons have very little of this element in their composition, not much attention has been paid to it—not as much as should be—for, owing to its chemical attraction for sulphur it serves to carry off much of this element which would otherwise combine with the iron, the sulphate passing off in slag. For hydraulic work, iron containing from 0.40 to 0.60 per cent. can be used to an advantage.

Castings used in hydraulic work must be sound, close-grained, and free from shrinkage. Only those that have had experience in this class of work know how difficult it is to accomplish. The exact chemical composition required in iron to produce such castings should be determined and lived up to closely. It is only necessary to analyse the iron for the four principal elements, for it is a well known fact that iron high in silicon is low in sulphur; and when silicon is low, manganese is low and sulphur is high. In foundry irons you must watch the silicon, phosphorus and manganese in order to obtain satisfactory results. In summing up, the mixture should contain from 1.25 to 1.50 per cent. silicon; from 0.60 to 0.80 phosphorus; from 0.40 to 0.60 manganese, and sulphur as low as possible. If you will take that for your standard, and melt your iron hot, you will see a decided improvement in the quality of your castings.

There is another point that must not be overlooked. In foundries using a large amount of scrap, say from 25 to 40 per cent., there is no fixed rule that you can adhere to. I always keep the scrap from the machine shop and sprews separate, and use these in the first of the melt, pouring my best work from this iron. Take this in addition to what No. 1 scrap I can pick out of the outside scrap pile, and let the other go into the common iron, which is to be used only in work that is not required to stand a pressure and has little or no machine work on it. This

takes a little extra labour, but is more than offset by the quality of the castings. The care and management of the cupola is another point which should receive its share of attention. The mortar used in repairing the cupola should be mixed with great care. If the mortar should run in the cupola, the first iron would come hard and dirty. For this reason one cannot be too careful with the mortar. The different brands of iron and scrap should be thoroughly mixed in the cupola, and not thrown in at random. Each charge of coke should be put in evenly, and the whole kept as level as possible. The iron should be drawn into a large ladle, and from that into smaller ones. By doing this the iron is thoroughly mixed, and good results are obtained. The writer is no great advocate of seeing how little coke can be used in melting iron, for more castings are probably lost by dull iron than in any other way. An extra fifty pounds of coke on a charge will sometimes save hundreds of pounds of castings, especially in work that is thin in places and has a large number of cores.

Current Topics

In the struggle for industrial supremacy coal and iron represent by far the most important agencies at work. Those nations which command the largest available quantities of both must lead in the race, and it is thus that to-day Great Britain and the United States hold the foremost positions. It is not altogether true, as has been thought by some, that racial instincts have been the dominating factors and that the Anglo-Saxon has forged ahead solely on this score. Geological formation, the immense deposits of iron ore and coal, within easy mining distance from the surface, and within comparatively easy access as well from population centres and the seaboard, have been potent influences, the effect of whose absence is shown in a remarkably clear manner in France, for example, which is to-day practically an agricultural country,—no longer a first-rate power, though possibly a first-rate nation. The gradual exhaustion of coal supplies and of iron ore has thus become a world problem of absorbing interest, and the persistent effort at acquiring new territories in yet undeveloped quarters of the globe may be largely due to the looming up of that time when furnace and mill at home will be threatened with idleness from want of material. Justification for territorial expansion may be attempted on the basis that such expansion is demanded by civilisation, that it is necessarily part

of the march of progress; but back of all this there is in nearly every instance the quest for mineral wealth, the foundation of the world's industries.

CHINESE trade possibilities will be an interesting topic for many a day, and to more than one nation; and it is well, therefore, to bear in mind that it is not excellence of quality, or low price, or both together in any one article that will suffice to capture the Chinaman's heart, or the contents of his purse, but rather the character of the trade-mark shown on the package of goods, or the colouring of the paper wrappings, or, mayhap, the degree of curl of the Chinese dragon's tail with which the speculative foreigner may have decorated his goods boxes. Reference to this feature of the Chinese trade problem has previously been made in these pages, but renewed attention has been directed to it by United States Consul-General Wildman, of Hongkong, in a recent report. In this he repeats that in putting up articles for the Chinese market, as has been emphasised by the British commission sent out to investigate the Chinese field, the manner in which goods are made up plays a most important part with the average Chinaman. He has certain symbols which he considers unlucky, and if you have a box of perfume, or matches, or any other article, so branded he cannot be persuaded to accept it even as a gift. Similarly there are many subjects which he considers lucky, and he exhibits a marked weakness for certain colours, being willing to purchase the goods bearing these lucky emblems and favourite colours whether he is very much in need of the articles or not. Many articles of necessity with us are not known to the Chinese. While cheap razors, needles, saws, knives, scissors, etc., are in great demand, table knives and forks and stoves are not to be thought of. Leather and rubber shoes are never used. Chinese brooms are made so cheaply and first-class Manila cigars are bought at such very low figures that there is no use considering these lines. Some kinds of machine tools are little better than scrap in China, because as long as labour remains at a few pennies a day, stones will be quarried, timber sawn, bricks made, piles driven, and goods transported by hand. Sewing machines, bicycles, pumps, etc., are in little demand, and those used are of the very cheapest character.

ONE fact which appears to be very little known or appreciated in considering China as a market for European and American manufactures,—and it is a fact which every one who has spent some time among the Chinese will emphasise,—is that, as Mr. Wildman intimates, only a very limited line of goods need be expected to appeal to them. Western civilisation has to contend in China with the inertia of several thousand years. Wide diversity of trade can come only from industrial development on a large scale along the lines followed by the despised "foreign devil," and what such development means in point of time cannot be gauged with even a shadow of pretence to accuracy. America has an ever-present object lesson in the fact that she has not yet learned how to civilise her Indians, nor can Great Britain boast of any material success in the land of the Ganges. With races so different radically from ours in all ways, in fundamental principles of language, in mode of life and thought, the work of the Western civiliser becomes one of stupendous proportions. With the Chinaman, too, we must admit that he was in a state of advanced civilisation many centuries before the Anglo-Saxon race, for example, had emerged from a state of almost absolute savagery, and he is only too prone, therefore, to remind us of the fact that, relatively speaking, from his standpoint, we are the barbarians, and that fire and sword, and opium and whiskey, mixed with a species of what might be termed "export religion," for which we ourselves seem to have no use, are curious civilising agents. This barrier of senti-

ment will long remain a far more formidable one to the spread of Western progress than the Great Wall itself of China, and will be infinitely more difficult to remove. And yet it has been taken lightly from the beginning of the attempted industrial invasion of China and is even now not valued at its true worth.

HIGH speeds and heavy feeds with machine tools are two features in machine-shop practice which have always suggested interesting possibilities in shop economy. Probably nowhere have they been carried into practice to quite so remarkable an extent as in the large machine shop of the Bethlehem Steel Company at Bethlehem, Pa., where, within about a year and a half, the output of all the tools has been almost quadrupled by the use of what is known as the Taylor-White process of tool steel treatment, devised by Messrs. F. W. Taylor and Maunsel White, and owned by the Bethlehem Company. What the process consists of is not told beyond this, that it embraces the use of a steel of special composition, and apparatus, also, for heating the tools to uniform and readily controlled temperatures. This apparatus is said to be applicable as well to the heating of tools of ordinary carbon steels so as to insure in them, too, greater uniformity than usual and higher qualities. Of the performance of the Taylor-White process tools, on the other hand, ample enough demonstration has been given in the Bethlehem shops to show that they are capable of unusual results, and to the progressive shop superintendent who may have hitherto considered his tool performances to be at a high efficiency level they must seem to prove that he is really far behind in what can be done. The amount of metal cut by a tool is clearly indicative of its working value, and as to this the Bethlehem shop records show that since the tests were commenced, about eighteen months ago, the weight of metal removed per hour per tool increased from 31.18 to 137.3 pounds, representing a gain of about 340 per cent. Within that time the main lines of shop shafting have been speeded up from 90 to 250 revolutions per minute, and further changes have been made in countershafts to speed up individual machines. The cutting speeds of the tools have been increased 183 per cent., the depths of cut 30 per cent., and the feeds 24 per cent. These figures speak for themselves. The underlying virtue of the Taylor-White process is that it gives to the steel the exceptional property of retaining a high degree of hardness, even when heated to a visible red heat, and it is thus possible with one of these tools to cut steel at a speed so great as to heat up the point of the tool to redness and have it continue to cut for several minutes at this speed and still leave a comparatively smooth finish on the work. But cutting metal in a lathe with a tool at red heat is something which the skeptic must see in order to believe. Opportunity for this, however, has been given, and is daily available, at the Bethlehem works.

WITH the exception of torpedo-boats and a few small pleasure craft, the American-built Russian cruiser *Variag* is to-day the fastest vessel afloat, having recently gone through a seven and a half hours' trial run at a speed of from 23.6 to 23.7 knots, or 27.14 to 27.25 miles an hour. The best hourly trans-Atlantic record, which now is held by the Hamburg-American Line steamship *Deutschland*, is 23 knots, or 26.45 miles, and this affords a very suggestive standard for comparison. We need go only a few years back to find a time when the large Atlantic racers, in point of regularly attainable speed, were far beyond anything that had ever been done in any navy, and their performances were considered practically beyond reach under the severe conditions of cramped space, light machinery weight, and others similarly restrictive to the designer. The United States triple-screw cruiser *Minneapolis* about six years ago developed slightly more than 23 knots during her contract trials, but, as

in the cases of most naval vessels, it was not expected that this would be demanded hour after hour in a run of several days, and it was not until the succeeding year, 1895, that practical demonstration was given for the first time that a naval vessel could actually hold her own with one of the crack Atlantic liners. This was afforded by the United States cruiser *Columbia* in her phenomenal run from the Needles, near Southampton, to Sandy Hook Lightships, the *Variag's* 23.7 knots give her to-day first place. The *Variag*, by the way, is the first American-built war vessel to have Niclausse water-tube boilers.

THOSE who have become imbued with the idea that we have reached almost the top notch in safety in railway operation will find some rather disconcerting figures in the chapter of acci-

THE RUSSIAN CRUISER "VARIAG," MAKING 27¼ MILES AN HOUR
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ship, off the American shore, in a few minutes less than seven days, or, to be exact, in 6 days, 23 hours, and 49 minutes, the average speed for the whole trip being 18.54 knots, or 21.3 miles an hour. The *Columbia* at the time was practically racing against the steamer *Augusta-Victoria*, of the Hamburg-American Line. Making proper allowance for the difference in the length of the two routes, the *Augusta-Victoria* having sailed from Cherbourg, the same rate of speed was maintained by both ships. Since that time high-speed, long-distance runs of war vessels have been repeated so that the impression has at last been wiped out that modern warships were simply boxes full of delicate and complex machinery scarcely fitted for the hard knocks which they were really intended to withstand. But among all the swift cruisers and battle-

dents of the United States Interstate Commerce Commission's latest report. In this the number of casualties to railway employees on account of accidents in the United States during the year ended June 30, 1899, was 37,133,—2210 being killed, and 34,923 injured,—or nearly two and a half times the reported total of killed and wounded in the British Army in South Africa up to July 1, which, in round numbers, has been given as 15,000. The total number of railway casualties, to employees as well as passengers and others,—trespassers, and people killed and injured at crossings,—was 51,743, the total number of killed being 7123, and of injured 44,620, and this, it would appear from published reports, far exceeds the total number of persons killed and wounded in the wars in the Philippine Islands and South Africa, including friend and foe. This

is a startling record. The bare figures, as published from year to year, do not convey nearly so emphatic a meaning as a bit of superficial comparison with the so-called butcheries of modern warfare.

With visions of exhausted coal supplies, even though the end be far off, come thoughts of power from sources other than coal,—from wind and water, and from the restless ocean waves and tides. Of water-power there are a goodly number of important installations, principally in the United States, where electric power distribution from them over comparatively long distances has reached a high state of development. In Great Britain, on the other hand, power from waterfalls is a scarce commodity and not much is to be hoped for in this direction, so that there is something of interest in a recent forecast of the country, with every hill or other point of vantage studded with huge windmills for generating electricity, to be subsequently distributed to manufacturing centres. Many years, however, would have to elapse before coal would become sufficiently dear to make such a scheme worth considering in a practical way. Wave motors and tide-power schemes have been almost endless in number. The former have, in a few instances, been used for light pumping work at seaside places, but such pumping outfits have been very far from demonstrating that the wave motor could ever be seriously considered as a prime mover where large powers were demanded; in fact, to-day it is little better than a toy. As to power from the tides, there is little to be said, except that much money has been wasted in vain endeavours to turn it to practical account. The tide-power scheme probably always will be alluring and also disappointing. The disappointment comes from the fact that very few people seem to take the trouble to figure out how much water and how considerable a fall are required to give any useful amount of power. A horse-power for a day of ten hours, for example, would require something like 120 tons of water falling from a height of 100 feet, so that a 500 H. P. factory, say, would need 60,000 tons of water at a 100-foot head. On the basis of 36 cubic feet of water to the ton, there would thus be over 2,000,000 cubic feet of water, and this would make a fair-sized pond, say about 1000 feet long, 200 feet wide, and 10 feet deep. There is in these few figures something that may help to open the eyes of the tide-power plan inventor and of those who are in the habit of putting money into such things.

Cheap power distribution from the colliery districts, where cheap coal may be had, is again on the tapis. The idea, as of old, is to make gas from the waste coal and to use this in gas engines driving high-tension electric generators whose output is to be carried by wire to the various points of consumption. With the inevitable development of the gas engine the scheme is every day assuming a more practical aspect, and it would seem to require little more just now to give to the world in concrete shape the dreams of the past half-dozen years. The 1000 horse-power gas engine is to-day a commercial product for which an encouraging demand has been found, and the promised extensive operation of by-product coking systems and producer gas systems should make gas available for gas engine use at figures with which the best steam engine performances of the present time would seem wasteful.

The limit of weight in the steam engine has, at the present time, been most nearly approximated in the machinery of the torpedo-boat and of the flying machine. In a recent paper before the Electrical Society of Cornell University, Dr. R. H. Thurston stated that the former amounts, in good practice, usually to about 100 pounds of displacement, of boat and contents, per horse-power of machinery. Maxim's steam

engine, of 300 horse-power apart from its boiler, weighs 300 pounds very nearly, or a pound per horse-power. Langley has certainly improved on this considerably, and may, perhaps, be able to bring down the weight, by, of course, enormously costly construction and material, to perhaps a half-pound. In marine work, Mosher has reached as little as four and a half pounds, and the torpedo-boat *Turbinia* is stated to have a weight of engines of but about three pounds. Boilers at a minimum weigh about ten pounds per horse-power of attached engine, in this class of work, and often rise to twenty or more. Torpedo-boats generally range between forty and fifty pounds per I. H. P., total, of which about two-thirds is boiler and one-third engine. Mosher's radical practice, by peculiar and ingenious methods of design and construction, brings the total down to about fifteen pounds, working at powers ranging from 1000 horse-power upward.

Speaking of some of the famous cathedrals built during the Middle Ages and the possible insight which they revealed into the science of mechanics on the part of their builders, Mr. L. Y. Schermerhorn, in a recent presidential address to the Engineers' Club of Philadelphia, remarked that, according to Mr. Gustav Lindenthal, the well-known American bridge engineer, those early builders employed a graphic method for determining the equilibrium of their arches and supporting columns, through the use of "Bauwage," or building balance. This consisted of a flexible cord in the form of an inverted arch, passing over pulleys at either end, the cord being drawn into an equilibrium polygon by weights suspended at various points along the cord, each proportionate in position and amount to those which the arch would be required to carry at its various points. The whole system was held in equilibrium by weights attached to the vertical ends of the cord after passing over the pulleys at each end, these latter weights being also measures of the horizontal force exercised by the system, or the horizontal thrust of the arch under consideration. By this method an equilibrium curve was obtained, the elements of which could easily be transferred to the arches, supporting columns, and buttresses to be erected.

This graphic method furnished an easy and reliable method for determining the amount and direction of the pressures arising in their arches, as well as the amount of the horizontal thrust to be provided for. Mr. Lindenthal states that most German engineers are familiar with this history of the "Bauwage," and the use which the cathedral builders made of it. These builders were the so-called Master Builders, who formed a guild extending over Europe in the Middle Ages, with traditions, usages, and methods pertaining to the building art, the higher knowledge of which was reserved for only a few in each country. While this use of a graphic method by the early builders prior to about 1585, for determining the equilibrium of arches, does not carry with it the assumption of a knowledge of the laws of statics involved in its principles, it does indicate that something more tangible than artistic instinct and intuition was guiding the old cathedral builders to the correct solution of their problems of construction.

An oil tank, about 82 feet in diameter and 33 feet high, had to be moved something like 160 feet laterally, and, at the same time, rotated 180 degrees on its axis, so as to bring the outlet on the west instead of on the east side. An account of how this was accomplished forms an interesting scrap of experience given in a recent letter to *Machinery* by Robert Grimshaw. The tank held 4000 tons of petroleum when full; its weight empty was 130 tons. Its thickness was from 6 to 12 millimeters, say, 0.27 to 0.53 inch. Its bottom was flat, and top rounded slightly. It rested

on a beton bed 32 inches thick. The first thing to do was to make the new beton bed in which it was to rest; then to build a mortared masonry wall 20 inches high above the level of the old and the new beton bed, and to ram and puddle the earth well in the space over which the tank would have to be moved laterally and turned, because the tank was not to be moved on rollers, but floated to its new position and turned while floating. The 130 tons weight (empty) on a base of 49 square meters gave a draft, for the vessel into which it was temporarily transformed, of about 11 inches. A depth of water of 16 to 18 inches over the cement bed would, therefore, suffice for towing the craft and turning it. As already mentioned, the tank was flat-bottomed, and this shape was not favourable to floating off the bottom of the "pond" made for it. The little matter of flotation, however, was started by pumping air into the tank until the bottom bulged downwards and let the water under it. It was then an easy matter for men with ropes to haul and turn the tank. Piles previously placed in position limited the motion and aided in leaving the tank exactly where it was wanted. The internal air pressure was kept up until the tank was in its new place, to prevent the upward water-pressure from dishing the bottom upwards; this upward pressure amounted to about 52 pounds per square foot. Naturally, a calm day was chosen for the operation, which was accomplished in an entirely satisfactory manner.

A NOVEL method of installing propeller shafting is described by Commander Harrie Webster, U. S. N., in a recent issue of the *Journal* of the American Society of Naval Architects. It appears that the United States torpedo-boat *Shubrick* was launched by the builders, the William R. Trigg Company, Richmond, Va., before her propeller shafting had been installed, for several reasons, the principal of which were the otherwise readiness of the vessel long before the contractors for this shafting were able to make delivery, and the desirability of clearing the ways as soon as possible. The launch was made on the last day of October, 1899, but it was March, 1900, before the propeller shafting was ready to be put in place, and as Richmond is about a hundred miles from the nearest dry dock, it became a question of considerable moment touching time and expense as to whether the long trip and the cost of docking could not be obviated. This question was promptly solved by the builders' determination to simply raise the stern of the *Shubrick* sufficiently free from the water to enable the work to be done from floats conveniently placed; and the complete success with which the scheme was carried out, together with the slight comparative cost, makes the event well worthy of special notice by shipbuilding and engineering experts. Commonly speaking, the steel ship, large or small, is supposed to be in the condition of a single element of a bridge structure, and consequently to possess the ability to withstand suspension at any point within the vertical through the centre of gravity without distortion or danger. This, however, like many another general hypothesis, is true only within very small limits, and if the attempt were made to suspend a steel craft of any considerable dimensions from a point in the keel directly beneath the centre of gravity of the vessel considered as a unit, the result would be disastrous.

THE bow of the *Shubrick* was depressed by the letting in of about 22 tons of water in the forward compartment, facilitating the immersion of the stem and adding to lateral stability during the suspension. The smooth water of the canal also was a favourable condition, but even with security from disturbance on the part of this element, the daring feature of the attempt remains as an illustration of the confidence that the builders had in the excellence of the hull work, especially when it is remembered that the hull plating of a torpedo-boat is but about ⅛ inch thick, and that

the length of the *Shubrick* is 175 feet. The approximate length of the *Shubrick* from the point of emergence to a perpendicular stern line was 62.5 feet, being somewhat more than one-third of her total length. A careful examination made during the period of the vessel's suspension failed to show that any undue strain was imposed on the framing or plating, and the fact that the shafting was emplaced without difficulty was *prima facie* evidence that such was the case. The angle of the inclination of the scow under the load of the *Shubrick* was brought almost precisely equal to that of the hull of the torpedo-boat, thus rendering the installation of the shafts a comparatively simple matter after the stern of the vessel had been raised. The cost of docking the *Shubrick*, at Norfolk or Newport News, with incidental expenses due to towing, insurance, and delay in work, was estimated by the contractors as in the neighbourhood of $1000, or about £200, while the expense of putting in the shafting after the manner described figured up only a little over $322, or about £64.

THE statistics of railways in the United States for the year ended on June 30, 1899, recently issued by the Interstate Commerce Commission, afford a vast amount of interesting information as to American railway capitalisation and valuation, earnings and expenses, number of employees, accidents, and other details. Under the head of equipment we are told that on the date above mentioned there were in service 36,703 locomotives, or 469 more than during the year previous. Of the total number reported, 9894 were classed as passenger locomotives, 20,728 as freight locomotives, and 5480 as switching locomotives; 601 were not classified. The total number of cars of all classes in the service was 1,375,916, an increase of 49.742 being shown in this item. Of the total number, 33,850 were assigned to the passenger service, 1,295,510 to the freight service, and 46,556 to the direct service of the railways. It should be understood, however, that cars owned by private companies and firms used by railways are not included in the returns made to the commission. It appears that the railways of the United States used on the average 20 locomotives and 734 cars per 100 miles of line; that 52,878 passengers were carried, and 1,474,765 passenger-miles accomplished, per passenger locomotive; and that 46,303 tons of freight were carried, and 5,966,193 ton-miles accomplished, per freight locomotive. All of these items show an increase when compared with corresponding items for the preceding year, ended June 30, 1898. There was also a decrease in the number of passenger cars per 1,000,000 passengers carried, and a decrease in the number of freight cars per 1,000,000 tons of freight carried. Practically all locomotives and cars in the passenger service were fitted with train brakes, and of 9894 locomotives assigned to that service 6128 were fitted with automatic couplers. Nearly all passenger cars were fitted with automatic couplers. With respect to freight equipment, it is noted that nearly all freight locomotives were equipped with train brakes and 45 per cent. of them with automatic couplers. Of 1,295,510 cars in the freight service on June 30, 1899, 730,670 were fitted with train brakes and 1,067,338 with automatic couplers.

HEAVIER rails, heavier bridges, heavier locomotives and heavier cars are the order in railway engineering, and the increase in tonnage to the iron and steel trades while the evolution is in progress will be an item of great significance. According to *Engineering News*, figures were recently given by two of the leading locomotive works of the United States showing the average weight of the locomotives turned out by them during the past year and during 1891. These showed an increase in the weight of the average locomotive of about 50 per cent. That is to say, the average locomotive turned out last year weighed about 1½ times as much as the

average locomotive turned out eight or nine years ago. Probably these figures somewhat exaggerate the progress made in that time toward heavier locomotives for standard freight and passenger service. The increased use of electric motors has nearly stopped the construction of small locomotives for suburban and other railways which was more or less of a feature at the beginning of the decade, and which served to reduce the average weight of the machines built. Yet making all allowance for this, it is plain that a great increase has taken place in the size of both passenger and freight locomotives. One firm which built 300 locomotives last year reports their average weight (locomotive and tender in working order) as 270,412 pounds. How great this increase is over the practice of a dozen years ago may be realised from a table, published in 1887, of the four most powerful locomotives in the world. They were two American mastodon locomotives (a Lehigh Valley, with 155,000 pounds total weight of both engine and tender, and a Southern Pacific, weighing 186,000 pounds) and two decapods, *El Gubernador*, of the Southern Pacific, weighing 239,650 pounds, and a Baldwin engine with a pony truck in front, weighing 224,000 pounds. The *El Gubernador* developed the enormous tractive power of 32,039 pounds, or just 39 pounds more than one-fourth the weight on the drivers. This was, indeed, enormous at that day, and yet in less than a dozen years from the time that was written locomotives were built with a tractive power of over 53,000 pounds.

FRED STARK PEARSON

CONSULTING ENGINEER OF THE METROPOLITAN STREET RAILWAY CO., NEW YORK

A BIOGRAPHICAL SKETCH

By W. P. Plummer.

AMERICA has been characterised as the land of young men,—the land where the destinies of big enterprises of all kinds are in comparatively youthful hands, and where the veteran in years is rapidly becoming extinct as a predominating active factor.

Of this younger generation of leading professional men Fred Stark Pearson, the consulting engineer of the Metropolitan Street Railway Company, of New York, the largest enterprise of its kind in the world, is an admirable example. He was born at Lowell, Mass., in 1861, and after a public school education, being obliged to seek early employment, secured a position as ticket agent at the College Hill station of the Boston & Maine Railroad Company. This being a flag station, young Pearson availed himself of the opportunity of visiting Tufts College, a short distance away. Electricity as a practical power at that time was just beginning to be recognised, and Professor Dolebar, of Tufts College, becoming interested in the young man, invited him to his lectures, and finally induced him to enter the college.

Of his course there a characteristic story is told. As station agent of the Boston & Maine Railroad, there were but few trains for which he had to sell tickets, but there were many trains which he had to flag after they had passed,—that is, to show a blue flag to tell a train that something is within five minutes ahead of it. This bothered young Pearson not a little; for this he had to leave his

classes at the most inopportune times and repair to the little station under the hill. He set about to find a way out of this work, and accordingly rigged up an electrical appliance that did the work for him. By his arrangement each passing train was made to complete a circuit by which the blue signal was shown behind it, and the flag was automatically withdrawn in the regulation five minutes. After that young Pearson attended his classes in peace.

He completed his studies at the college, graduating in 1879 as a chemist and mining engineer. From 1880 to 1881 he was instructor in chemistry at the Massachusetts Institute of Technology, but at this he did not stop; he re-entered Tufts College, taking up civil and electrical engineering, and in 1883 graduated as a civil and electrical engineer. From 1883 to 1886 he was instructor of mathematics and applied mechanics at Tufts.

From 1886 to 1888 Mr. Pearson was engaged in mining engineering in various parts of the United States and Brazil, and in 1888 accepted a position as manager of the Somerville Electric Light Company, at Somerville, Mass. In 1889 he resigned this place and accepted the position as chief engineer of the West End Street Railway, of Boston, Mass. At that time the West End Company was proposing to undertake the herculean task of equipping its entire system with electricity. It was a new departure for any street railway company to make, especially on so large a scale. Mr. Pearson was then a very young man and comparatively unknown in this kind of work, but his extraordinary genius carried the company triumphantly through all its perils, and established the electric system as a splendid success, not only for the West End Company, but for all others who were interested in this development in all parts of the world.

Mr. Pearson in his specifications demanded electrical apparatus which was at that time not made by manufacturers, and he was often obliged to work out many of the details himself. The large belted machines in service at the present time, as well as the direct-connected units, are the results of Mr. Pearson's requirements from the manufacturers and contain many of his ideas. The first 500 K. W. belted generator ever constructed was built under specifications drawn up by him for the West End Street Railway, of Boston.

So pronounced was the success of electricity as power for street car propulsion in the city of Boston that the officers of the Brooklyn Heights Railroad Company, of Brooklyn, N. Y., shortly afterwards decided to adopt it for operating its various lines in that city. Mr. Pearson was, accordingly, made consulting engineer, and the eastern power station of that company was designed by him, being the first direct-connected plant installed in this country for street railway service. It was somewhat larger than the central power station in Boston and more modern in its design.

In 1893 Mr. Pearson was instrumental in organising the Dominion Coal Company of Canada, and was appointed its chief engineer, serving also on the board of directors. In order to increase the output of this company, and in the interest of Mr. H. M. Whitney, of Boston, Mr. Pearson, on one of his many trips abroad, made a careful examination of the coke industry, and as the result of his investigations the New England Gas & Coke Company and the Massachusetts Pipe Line Company were formed. As engineer of the Dominion Coal Company Mr. Pearson had in charge the re-construction of shipping piers at Sydney and Louisberg, Canada, the coal handling apparatus at Montreal, the building of the Sydney & Louisberg Railway, and the operation and equipment of the company's mines at Cape Breton in general.

In 1894 Mr. Pearson accepted the position of chief engineer of the Metropolitan Street Railway Company, of New York, acting as the engineer of the Whitney - Weidner - Elkins syndicate. The Columbus Avenue and Lexington Avenue cable roads at New York were constructed under his supervision. Notwithstanding the state of efficiency to

which the cable roads had been brought, Mr. Pearson could foresee that electricity would be more desirable for the operation of the system of the Metropolitan Company, and after making a careful investigation of the roads in operation at Budapesth and Berlin, as well as the climatic conditions of both cities, he designed a system of underground conduit construction to meet the existing conditions in New York City. The first line to be installed was on Lenox Avenue, about three miles in length. The excellent service given by this road demonstrated that it was perfectly feasible, and within the last three years the Metropolitan Street Railway Company has accordingly constructed eighty-one miles of conduit roads, and work is now in progress to change the cable roads over to electric operation.

The electric power station of the Metropolitan Company at Ninety-sixth Street and the East River, which, when completed, will be the peer of all stations in the world, having a capacity of 70,000 horse-power, was designed by Mr. Pearson.

On account of poor health Mr. Pearson was obliged to resign his position with the Metropolitan Street Railway Company in 1898 and take a long trip abroad. In October of that year he again returned to this country, and, purchasing the famous schooner-yacht *Coronet*, took a cruise of three months in West Indian waters, visiting Santiago, Havana, and other ports, combining pleasure with business. Subsequently he went to South America to develop a railway, light, and power scheme at Sao Paulo, Brazil.

Mr. Pearson has had entrusted to him construction work amounting to millions of dollars, being the direct representative of several large American, Canadian and English syndicates. He has acted as consulting engineer to the following companies:—Brooklyn Heights Railroad Company, Toronto Street Railway Company, Montreal Street Railway Company, Winnipeg Street Railway Company, St. John Street Railway Company, Halifax Electric Tramway Company, Consolidated Traction Company of New Jersey, Metropolitan Elevated Company, Chicago; Syracuse Rapid Transit Company, Staten Island Electric Railroad Company, Atlantic Coast Railway Company, City of Birmingham Tramways, Union Railroad, Providence, and a number of other companies. He has also made investigations and reports on the street railway properties in Liverpool, England; Brooklyn, N. Y.; Washington, D. C.; Kingston, Jamaica, Havana, and Santiago, Cuba, and in a number of other cities, both in this country and Europe. He is also a director in the American Air Power Company, Electric Storage Battery Company, New York Gas and Electric Heat and Power Company, and Dominion Coal Company, and is further identified with a syndicate in the development of automobiles.

Probably no one who has not been in close contact with Mr. Pearson has any correct appreciation of his admirable qualities or of his extraordinary ability. He is, moreover, a man of great modesty and extensive information in all departments of human industry,—withal, a man of such a genial and attractive personality that those associated with him cannot fail to become attached to him by the very strongest bonds of affection and esteem.

PHOTO BY PACH BROS., NEW YORK

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SEE PAGE 525

CASSIER'S MAGAZINE

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THE PARIS EXHIBITION

MACHINE TOOLS, CRANES, BOILERS, AND ENGINES

By Joseph Horner

THE GATEWAY TO THE EXHIBITION

THE Exhibition at Paris is a revelation to many, not in its vastness only, but in the very tangible evidence which it affords of the changing industrial relations of the great manufacturing countries of the world. To see the Exhibition properly in a limited period is a huge task. The best course to adopt in any case is probably to spend the first day in walking about the buildings, taking the main bearings and locations of the mechanical sections, and then work through them afterwards in detail. The famous moving platform affords no aid except to the sight-seeing public. It skirts one side only of the Champ de Mars, and then goes off to the Invalides, and the Street of the Nations by the Quai d'Orsay. But it gives one some idea of the extent of the ground covered.

The American machine tool exhibits are placed at much disadvantage, because they are divided between the

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A PORTION OF THE MOVING PLATFORM

Champ de Mars and Vincennes, the latter comprising by far the larger portion. The sending so large a section to Vincennes, five miles away, is a blunder. Better to have abandoned some of the buildings in the Street of the Nations, or have extended beyond Passy than consign these fine machine tools, and the splendid locomotives, British, French, Swiss, Italian, Belgian, and Russian, with palatial carriages, motor cars, and oil engines to a spot five miles from the Champ de Mars. Now, any one who is interested in machine tools or motor cars must divide his time between the two places, and while gas engines are at the Champ de Mars, the oil engines are at Vincennes. From two and a half to three hours are inevitably lost in getting there and back.

In regard to the effect of separating the exhibits thus, comparatively few people go to Vincennes, and the arrangement is unfair to the Americans. On the other hand, those who do take the journey go there with a definite object, being specially interested in the subject, and not idle sight-seers.

The American machine tool building at Vincennes has been built by, and at the expense of, the exhibitors themselves. The incidental expenses of transit and erection have been also heavy. A gentleman in charge of one of the largest sections told me that the total cost of exhibiting,—quite beyond the cost of the machines themselves,—would run his principals into between $30,000 and $40,000, and said that at Havre the charge for a lighter was 750 francs a day. Under such depressing conditions the American firms deserve much praise for making so excellent a show.

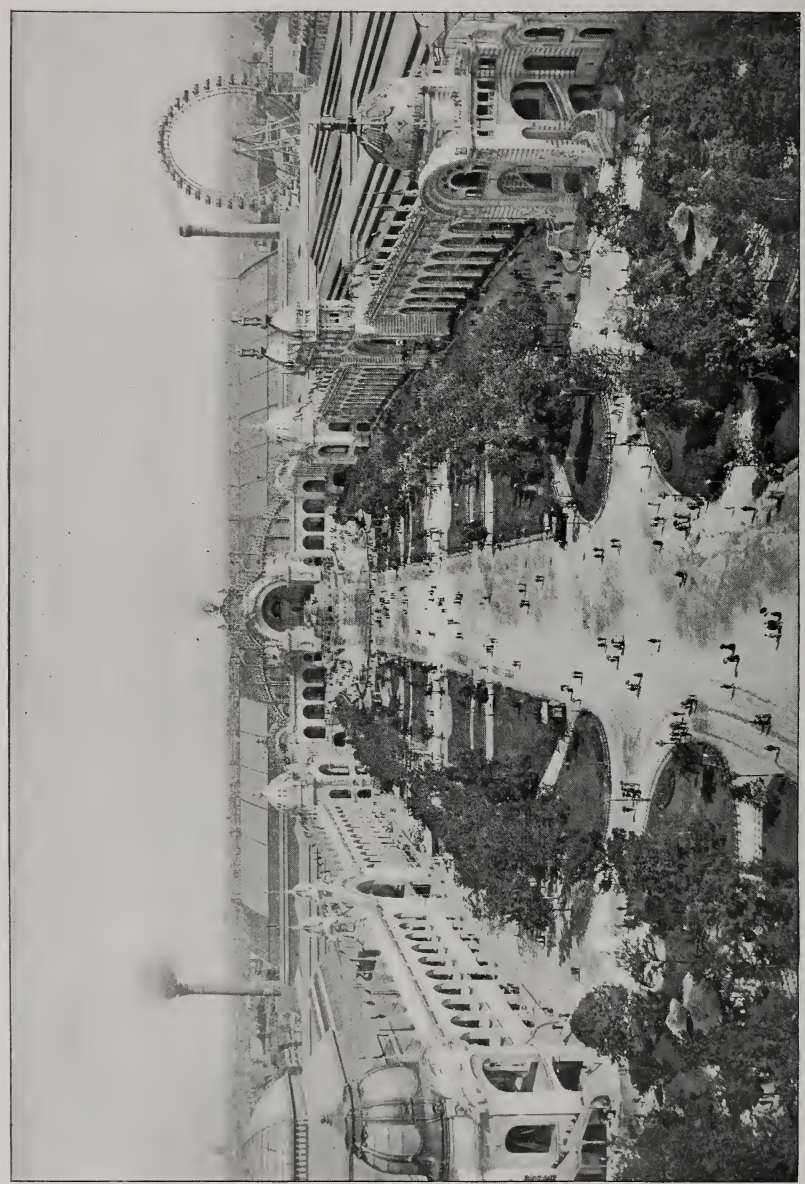
The American exhibit suffers in an-

other respect besides division by comparison with those of the foreign nations. This is partly accounted for, as was explained to the writer, by the unwillingness of the firms to send over anything of large dimensions or unusual pattern which might be left on their hands at the close of the Exhibition. The result is that most machines there are of standard and familiar forms. At Vincennes we meet with old friends, well-tried types that have made the names of the firms well known in shops in Great Britain and on the Continent, as well as in America. There are some novelties also, a few being exhibited for the first time, and numerous improvements in so-called minor details, many of which would be passed unnoticed by a casual observer, but which, nevertheless, materially influence the output of a machine. Most of the well-known names in American machine tool practice are there, and about half a dozen of the stands are of large area and very completely equipped with representative tools, quite a fair number of which are electrically driven. It is a large collection, full of interest, and will repay a lengthened study. Among its principal features are the large number of gear cutters, Brown & Sharpe, Gould & Eberhardt, the Fellows, the Rice, for planing bevel gears for chainless cycles and similar small work, an entirely original and most interesting machine. Turret lathes are a leading feature. The Gisholt lathes make a fine show, together with the Jones & Lamson, the Pratt & Whitney, and others. Those which attract the most attention, because they are the most recent, are the Conradson lathes, at the stand of Markt & Co.

The magnetic chucks at Vincennes likewise attract much notice; also some

THE EIFFEL TOWER AND GREAT GLOBE, WITH WORTHINGTON PUMPING STATION TO THE LEFT

novel countershafts by the Builders' Iron Foundry, a large electrically-driven wheel lathe and quartering machine by Bement, Miles & Co., and pneumatic



A GENERAL VIEW OF THE EXHIBITION BUILDINGS AND GROUNDS

tools of the Boyer and other types. But though these are the more novel features, the well-known and long-tried tools of standard types are of nearly equal interest, and constitute the major portion of the exhibit. Machines of exquisite precision for screwing, turning, boring, and machines for gauge grinding occupy a prominent place, and are well represented. There is an infinity of points of detail which appeal to the practical man.

Those who are able to compare this Exhibition with that of 1889 will note the great advances which have been made by American, German, and French firms chiefly. To be candid, British machine tool makers have an insignificant show beside those of other countries. The tools that are shown are mostly very good, but there are far too few of them. Scarcely any of the older firms are represented. The best exhibits are those of the younger manufacturers who were unknown a dozen or fifteen years ago. But they are nearly lost in the great maze, and foreigners will estimate Great Britain's position by her status in the Exhibition, and in regard to machine tools numerically she comes far behind either America, France, or Germany.

So little does Great Britain's prestige count that few of the attendants at the foreign stands are able to converse in English, and there are few catalogues prepared in the English language, nearly all being in German and French. And you will search in vain in the French official catalogue devoted to steam-engines and machine tools for any account of Great Britain, though every other nation in Europe, from Germany to Roumania, is given a place there, with portraits, and a lengthy notice is afforded to the United States. Great Britain has kept too much aloof from the Exhibition. Yet never was there such an opportunity for advertisement as in this immense concourse of the nations from the ends of the earth. These remarks have reference to machine tools and engines chiefly. In several other sections Great Britain is well represented.

To the possible objection that an exhibition such as this is not an accurate gauge of the relative positions occupied by the manufacturing nations, the reply must be that to the millions who visit it, it is the only gauge,—the visible, tangible embodiment of the relative status of the various nations. Though trade is brisk now, it will not always be so, and then the result of this aloofness will be felt.

Most Englishmen must feel astonishment at the headway made by France, Germany, and Russia in recent years; it is a revelation which, suspected by some, and known to a few, was undreamed of by most. Germany and France have the largest exhibits of machine tools at the Champ de Mars. But if the Vincennes annex is included, the Americans come out a good first, both in size and in point of interest. Belgium, Switzerland, and Italy make comparatively little show in machine tools, though strong in other productions. A feature that is likely to astonish many is the appearace here in force of Russia. In metallurgy chiefly, in railway plant, and in machine tools, though in a lesser degree, she occupies an important position. And it is not that of an amateur, but of a people in possession of sound practical knowledge. That great, and until recently inert nation, has definitely entered into rivalry with the western nations of Europe, and we may anticipate that not many years will elapse before that rivalry will be severely felt. The nation that figures so largely here in metallurgy and in machinery, and that is able to construct a trans-Siberian railway without outside help, is capable of great things.

After a somewhat extended study of the machine tools and other classes of manufactured articles at the Exhibition, the writer may be permitted to offer some observations on what appear to him to be the more salient features that characterise them. In conversation, a tinge of national jealousy is noticeable on the part of the attendants in speaking of the exhibits of foreign countries. Few care to admit greater excellence of design and workmanship on the part of

LOOKING DOWN THE STREET OF THE NATIONS. A GLIMPSE OF THE UNITED STATES BUILDING

other nations. This feeling exists with British towards Americans, and with Americans towards German and French. Leading features in designs which have made the reputations of some firms are depreciated as having been known years ago, apparently oblivious of the fact that nearly all perfected designs have floated in embryo during long periods. Another fact is, that firms have had a good speciality, but have never pushed or advertised it, and it has, therefore, remained unknown and unappreciated outside the circle of their own clientele until rival firms have produced a very similar article, and by dint of advertisement have quickly made a reputation so wide that they have been able to confine their energies wholly, or to a large degree, to the manufacture of that speciality, with all the advantages, mechanical and commercial, which result from that specialisation. The older manufacturers then feel sore on the subject, and speak disparagingly of their rivals, while the fact remains that the rivalry arose from their own indifference or self-confidence.

It is generally admitted, and the fact is unquestionable, that the German tool makers are becoming the most formidable rivals of British and American manufacturers. The French firms come in a good second, though their competition will not be felt to anything like the same extent as that of the Germans will,

at least not yet. But it is impossible to give much study to the best French exhibits without being struck by the high degree of excellence attained in these, both in the light and the heavy tools. This applies to the ordinary types, and also to some fine instruments of precision, and small tools. There are, however, in this section some machines and some portions of machines, in other respects good, which are decidedly rough, —lumpy and imperfect castings, coarse tooling, poor finish,—and the marvel is in some cases that these should ever have been sent for show. There is

GREAT BRITAIN'S BUILDING

scraping to be seen that would set the hair of a good mechanic on end. I noted on an otherwise well-made lathe a rack cast so badly that it would have been "scrapped" in any decent shop. The teeth had excessive flank clearance, and a very variable amount of bottom clearance, and as the face of the rack was tooled bright, these inaccuracies were revealed in a very glaring manner. In a very few of the French lathes cast teeth are used for the back gears and change wheels, and also for double helical wheels, these being bolted together on the central plane.

The above samples of this kind form a minority in the French section. The best exhibits here are of high excellence. Some are very fine tools and instruments that would do credit to any firm. The workmanship in the German section is more uniform, as is also the British. Belgian tools are but fair; the Swiss, though too few in number, are of high quality and marked by considerable originality.

One of the first impressions received after a tour round the machinery sections of the Champ de Mars and Vincennes is the immense variety in detail in machines of the same class. This is, perhaps, most noticeable in the lathes, as is to be expected; but the same thing

THE PALACE OF ARTS

occurs in nearly all other machines. On many of the Continental ones we miss the severe simplicity of the standard types of British tools, and in some cases it seems as though detail and complication were carried to a needless extent. This, however, may be in appearance only, because one cannot judge, except by inference and opinion, of the commercial value of the machines at rest in an exhibition, and only a small proportion are seen in operation. The true test must be in the workshop. Further, the present tendency in machine tool design is towards increased complication, with the view of rendering them semi-automatic or entirely so, a fact to which due weight must be given when making a critical estimate of machine arrangements.

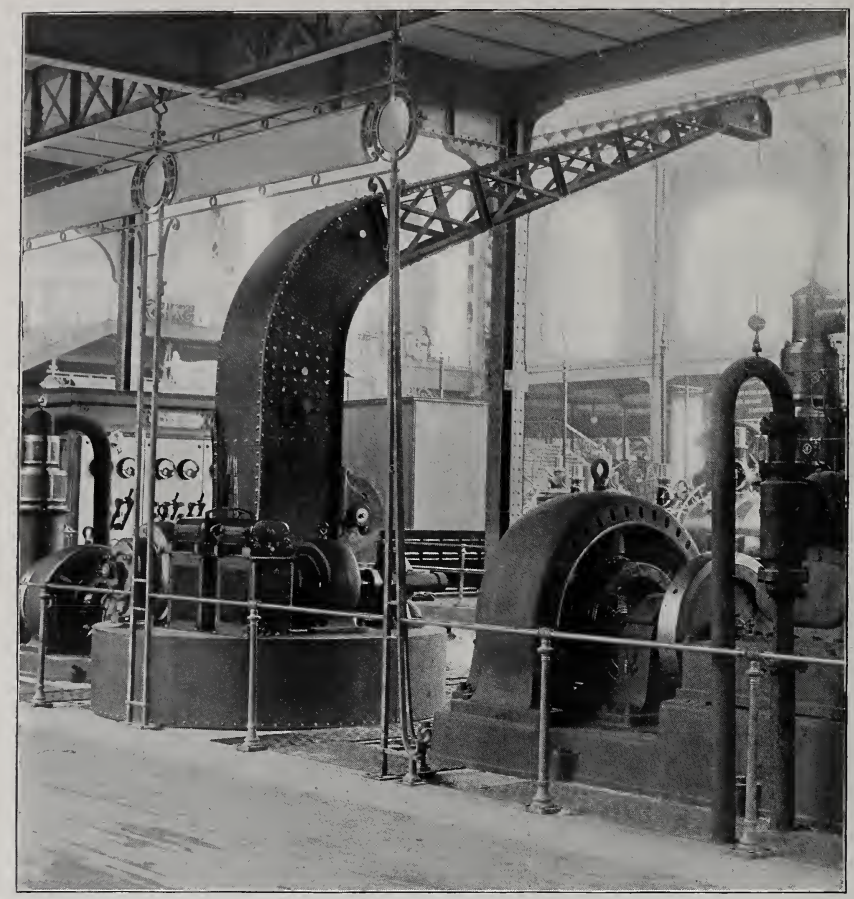
The high regard in which the American machine tools are held on the Continent is evidenced by the large number which are seen at the foreign stands, and by the still larger number of foreign make which are fashioned more or less after American models. There are several agents, too, for American firms, and one of the interesting stands at Vincennes is that of an agent, which shows a fine and varied selection of American tools, several of which are as yet little known in Great Britain. The American influence is more marked in present Continental design than the British. At German and French stands there are very many American types of lathes, vertical boring mills, universal grinding machines, screw machines, and other imitations, and modifications of well-known types, and, as imitation is the sincerest form of flattery, the fact may be accepted that these, and not the British, are the favourites on the Continent. Machines which have proved eminently successful are being imitated. There are several flat turret lathes, several adaptations of the nests of gears of the Hendey-Norton type, and several very heavy turret lathes built for tooling castings of considerable dimensions.

Clearly no firm can hope to keep a monopoly of a good thing very long, and the wise course, therefore, is to make hay while the sun shines, and do as big a trade as possible while the halcyon days last. And the best policy for purchasers is to work a new machine tool to its fullest output, assured that in about half a dozen years or less something better will be obtainable, modelled probably on the original, but of greater capacity or power, more rapid in action, or more fully automatic. But though there is so much following of older designs, as of course there must be, yet there are many novel and original points of detail which arrest attention. After all, there can be little absolute originality in machine design, so that the question of copying is rather beside the mark, since the main point is the production of a good machine tool.

Electric driving of machine tools is well represented, chiefly in the German section, and in a lesser degree in the French, lathes, drilling, and many other machines being so operated. In fact, at some stands it is nearly universal. The Germans are evidently taking a lead in this. It is not easy to trace details in some of the examples; in some cases it is quite impossible to do so because the practice of encasing everything that can be covered in is so common.

A leading feature of the Exhibition that must strike even the most casual observer is the important place occupied by gear cutting machines of the planing type. They greatly predominate here over those in which rotary cutters are used. The numerous ingenious designs of these, all having the same end in view,—that of planing perfect teeth,—require a considerable time to master. They point to the issue that has been growingly apparent to the observant individual, that the days of forming bevel gears of large size with rotary cutters are numbered, and that the bevel wheel cutting machine of the future will be of the planing type, the only rival to which will be the generating machine.

Among the numerous gear cutting machines at the Exhibition there is only one of the generating type,—the Fellows,—one of which is exhibited at the Champ de Mars, and another at Vincennes. The most original machine in



A ONE-TON TWO-MOTOR JIB CRANE BUILT BY THE COMPAGNIE INTERNATIONALE D'ELECTRICITÉ, LIÉGE, BELGIUM

the Exhibition,—the Rice automatic bevel gear cutter, made by the Rice Gear Company, of Hartford, Conn., U. S. A.,—is shown in operation at Vincennes. It is novel from inception to completion, and is a direct result of the demand for chainless cycles. The remarkable fact is that bevel teeth are cut theoretically true with a rotary cutter, but the marvel is explained as soon as the action of the machine is grasped. Instead of using a single form tooth, as is the practice of all other form machines, an entire enlarged wheel is used, which at first sight seems expensive, and open to the objection of possible inaccuracy. But it is not struck out, but generated on a Bilgram machine, and the enormous number of gears of a single size required in the cycle industry causes the expense of an entire form wheel to count as for nothing. Moreover, any wheels the size of which would be included within the pitch cone of the master wheel can be cut by its aid.

Another feature to be seen at the Exhibition is the planing of single helical bevel teeth true, and not diagonal only, a correct screw tooth being formed with a reciprocating cutter. There are also several hobbing machines for cutting true worm wheels, the most original being that of J. E. Reinecker, of Chemnitz-Gablenz, shown on page 463. The principal feature in the design is that the hob is tapered to cut its way

into the worm wheel blank endwise. Since it has not to be fed depthwise into the blank, as in other kinds of machines, the correct centres are set once for all. This is seen at the right-hand side of the illustration, where the tapered outline of the hob is clearly visible, and the supporting bracket for the arbour. The blank is on the same spindle as the master wheel, which is seen to the left of the machine.

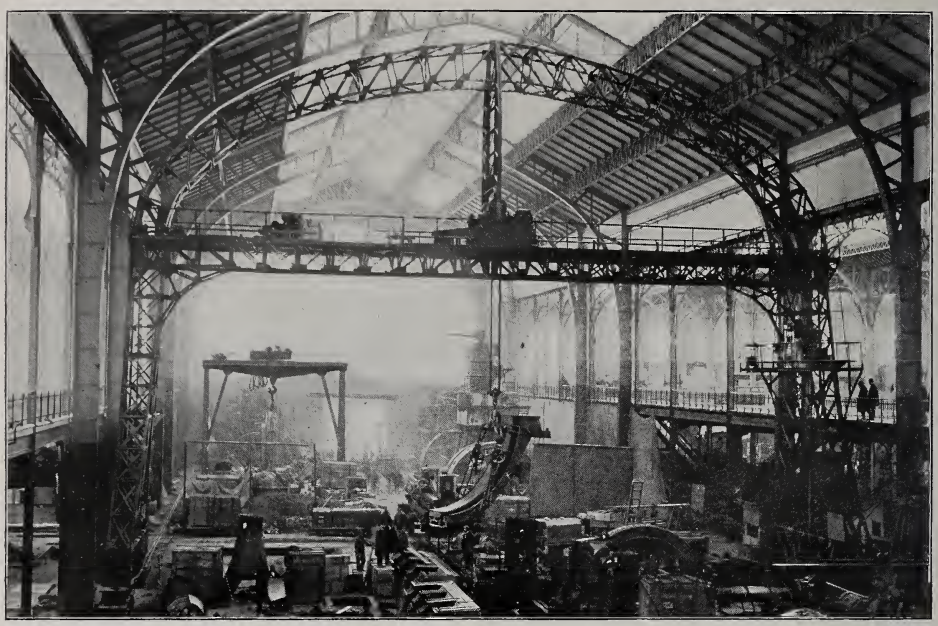
A notable feature in Continental practice is the very general use of single helical teeth for back gears. Comparatively few British or American tools have these. Whether there is any advantage in their use or not, they are nearly universal in French and German machines.

The gears in the various exhibits and the gear cutting machines indicate the growth of a better practice than the older one with which we have been so long content. It is not only that cut gears are found on machine tools and even on cranes for which cast teeth were generally used a few years since, but that approximations to correct tooth profiles are not now considered good enough. For large and for small gears alike theoretical accuracy is sought, and is embodied in the forms of cutters, and in the essential designs of machines. Hence the general predominance of the involute, and the displacement of the cycloidal form, because the first named is more readily produced by cutting than the second. The cutting of true bevel teeth by planing of worms with rotary milling cutters, and the hobbing of worm-wheel teeth with hobs of worm section, all point in the same direction. The importance of, and the striving for, correct gears have never been represented in so extensive a degree as they are at Paris this year, and it strikes the writer as one of the most novel aspects of the section devoted to machine tools.

Another point observable is the increasing application of automatic movements to tools, less and less being left to the workman. Not only so, but the use of stops for arresting and reversing movements are increasingly eliminating the need for measurement. If a number of similar pieces have to be made, the position of the tool, or tool slide, or work slide, or holder must be fixed. Micrometric divisions are more common, fine divisions on hand wheels, on discs, on such edges as are most suitable, and pointers show at a glance how and where to fix a movement.

Another detail is the extent to which sliding and wearing surfaces are protected, and gears and vital parts enclosed. On a good many machines the flat slides are never exposed, no matter what the position of the saddle or carriage may be. Gears are enclosed within knees and heads, and are never seen except on the removal of their coverings, while gears that are necessarily outside have wire, or sheet iron guards, affording primarily protection from accident, and, in the case of solid sheet guards, protection from dirt and chips. This is carried out partially in the majority of cases, absolutely in a good many. It is so fully adopted in some that it is nearly impossible to tell on looking at the encased machine in what way its movements are operated, except by inference. Among many examples of enclosed wheels may be mentioned the back gears of lathes, the feed gears at the side of the tables of slotting machines, the table driving wheels of planers, and the gears of milling machines. In fact, the practice is carried farther than is necessary as a mere danger guard, because in many cases wheels high up out of reach are so enclosed, and the idea apparently is to embody in a design as complete a rounding off or concealing of all angularities in casings as possible.

In milling machines the practice of setting the spindles to work at any angle in the vertical plane is common. Such practice is as yet rather unusual in British and American machines. There is no objection to it, except it be on the risk or difficulty of setting the spindle exactly vertical or horizontal when required. That, however, is a question of accuracy of workmanship in the machine. The advantages of being able to mill anywhere in the range of 90 degrees are so great that we may expect to see these Continental machines mak-



ELECTRIC TRAVELLING CRANE BUILT BY CARL FLOHR. WORKING LOAD, 25 TONS

ing their way into many shops, and into foreign markets.

Emery wheels make a good show in the French section, and give evidence of a large industry in this direction. It is a fact that many machines sold by firms having houses in Great Britain are manufactured on the Continent. Few in the French section are instruments of precision, that is, for grinding to gauge. They are floor machines chiefly, for the rougher class of workshop operations, such as grinding the edges and faces of work for good appearance. Most are of the common type, with two wheels at opposite ends of a spindle, or one heavy wheel in the centre of a spindle. There is a considerable number of face wheels, those with vertical and horizontal spindles being well represented. There is a general absence both of safety rings to these and of guards to the disc wheels, which are fitted so frequently both to the best British and American grinders of these types. The rests and their method of fitting and adjustment are varied and numerous, and form an interesting study in themselves.

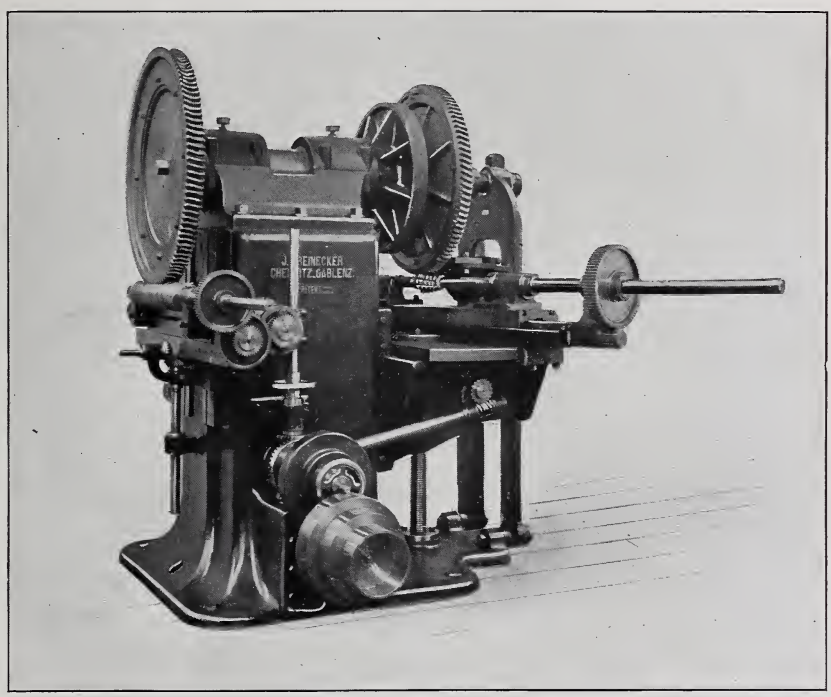
The department of metallurgy is one of the most fascinating in the Exhibition. To the technical observer and to the man in the street alike, it is a fairy palace of steel and copper. Tapering columns, arch, pediment, entablature, moulding and frieze, boss and tracery, circles and scrolls realise the ideal of the artist in steel, iron, and copper,—trophies of industries which are chiefly the creation of the latter half of the present century.

Whenever I have seen castings or groups of castings in the Exhibition I have examined them. Allowing for the fact that they were made for show, ample credit must be given to the craftsmen of the Continent who can, if they choose, make perfect castings, many of which are of complicated forms. There are, however, exceptions; a few are so rough that self-respecting firms would be disposed to consign them to the scrap heap.

The cranes at the Exhibition are numerous, but, being widely scattered, have to be sought for. They may be divided broadly into those of large and special types, and those of small and

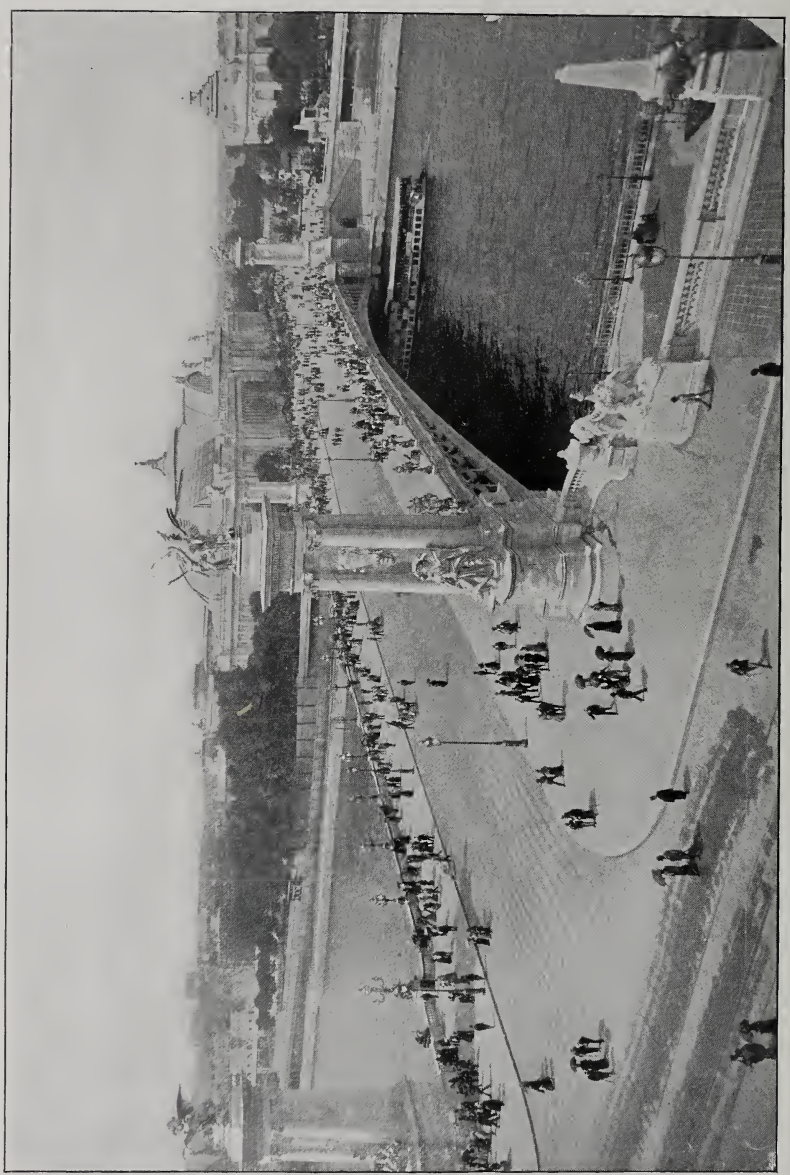
more standard types. The French makers of small cranes might do well to take lessons from those of British manufacture. They have the fault of being all too light, and possess a gimcrack appearance. Not in one part only, but in each member, they are too light,—in frames, shafts, gears, even to the very eyes for the hoisting drums, in some cases bits of ⅜ or ½-inch rod cast in. The wormanship and finish also are capable of much improvement. The best cranes of the portable type in the Exhibition are of British make,—those application the attendant took me to the platform and was putting the crane through its paces. The great travelling crane, or Goliath, of Carl Flohr, was also started in a few minutes.

In criticising foreign cranes the observer must dismiss from the mind ideas derived from British and American practice. The first point that strikes one is the general Continental plan of dispensing with the drum or barrel so universal in our cranes. Not only small cranes, but also the largest traveller in the Exhibition has its chain thus working on



WORM WHEEL HOBBING MACHINE BUILT BY J. E. REINECKER, CHEMNITZ-GABLENZ, GERMANY

of Grafton & Co.,—two excellently designed and well-made horizontals near the Eiffel Tower; and one by Jessop & Appleby Bros., Ltd., on the ground floor of the Palace of Civil Engineering. But it is a great pity that no provision is made for operating these, as there is with some of the foreign electric cranes in the Exhibition. There is a fine electrical gantry crane by Caillard & Co., of Havre, and within two minutes of my a recessed chain pulley, and the fall of the slack is taken in short lengths. There is no novelty in this arrangement in France. A novelty, however, is the application of electricity for driving nearly all cranes of all types. In one particular jib crane by the Compagnie Internationale d'Electricité, of Liége, shown on page 460, two motors are used, one for lifting and lowering, the other for slewing, and the gears are en-



THE ALEXANDER III. BRIDGE, SEEN FROM THE SOUTH BANK OF THE SEINE, WITH THE PALACE OF ARTS BEYOND

tirely enclosed, so that the crane looks like a simple outlined machine, with none of the details of its mechanism at all apparent.

It is evident that the ideas of crane makers differ even more widely than do those of machine tool builders. A significant difference is that while in Great Britain, at least, there are comparatively few electric cranes except the travellers, there are few cranes in the Exhibition, from the largest to the smallest, which are driven otherwise than electrically. Even the smallest, flimsiest, cheapest portable cranes, which would be hand or steam-operated in Great Britain, are here driven by motor and belt.

The exhibits in this line which attract most attention are the great Goliath, of Carl Flohr, in the Champ de Mars; the Titan by Jules le Blanc; the Titan by Daydé & Pillé; and the Temperley transporter, one of which is at work at Vincennes, and a beautiful model of which is in operation in the Champ de Mars. The Goliath, of Carl Flohr, is one of the sights of the machinery section in the Champ de Mars. It stands over the exhibit of Reinecker, and makes a vast span of almost 90 feet, reaching nearly to the under sides of the arched roof girders. In some respects it is a novelty in crane work.

It is operated from a platform at one end, and a little below the bridge girders, a patented device dispensing with the necessity for the use of more than one lever for each motion. It has four motors, two crab motors for lifting, and operating simultaneously, a motor for the traverse of the trolley, and one on the bridge for travelling. The advantage of two lifting motors is that the crane need not stand idle if one of them should be in need of repairs. The lifting force is duplicated on each side, through enclosed worm gears, the worm thrust being taken against ball bearings, and the worms,—cut in bronze,—run in oil baths. They are cut by milling. The chain fits in a cupped drum with falls, according to standard Continental practice. The total weight of the crane is somewhat over 100 tons, and its working load 25 tons.

A characteristic feature of the Exhibition is that the power plants are centralised, instead of being scattered. All the boilers are located in two areas only, one area being occupied by the French firms, the other chiefly by foreign ones, and the steam generated is conducted through main pipes in culverts beneath the ground to the engines grouped in the Electricity buildings adjacent. All the smoke passes into two chimneys, one chimney serving each group of boilers. They are of immense size, and are conspicuous objects from all parts of the grounds. They are 262 feet high by 17 feet diameter at the bottom, and about 15 feet at the top. The brick work is arranged in different colours, highly decorative in character, making of these chimneys objects of art and beauty, in harmony with so much of the structural work about the Exhibition.

The boilers are arranged in each house in two parallel groups with a central tramway between them for the supply of fuel, and an ample width on each side between the boilers and the Exhibition buildings, so that the boilers, which are exhibits, are open to public inspection. Something like 20,000 horsepower is utilised,—5000 for power and 15,000 for lighting. A great deal of the work lies underground in conduits, consisting of water supply pipes, and waste water pipes from the condensing engines. The power is transmitted wholly by electricity, forming in this respect an installation unique in the history of exhibitions. There are no belts, and no exhaust steam, all the engines being condensing. It affords an interesting and striking illustration of the great advances that have been made in this department in a very few years in regard to the boilers, the engines, and the generators.

The boilers are of the water-tube types, the exceptions being some elephant boilers and six Galloways, three of which were in actual use at the time of the writer's visits. The engines are of the type which are coupled direct to fly-wheel generators, these being chiefly of the three-phase kind. Most striking, perhaps, is the immense size of some of

the engines, and as they are nearly all grouped in adjacent areas, the sight is rendered more imposing than if they were scattered. Horizontals predominate, but there are several large verticals. Another notable point is the high character of the workmanship and finish, non-working parts being finished as highly as if they were for sliding surfaces, while valve gears are simplified, few of Corliss type being used, and sight-feed lubricators are common. There are also several fine engines not actually engaged in the generation of power, and a 650 H. P. gas engine to be driven by blast furnace gas.

Two departments in which foreign exhibits make a large figure are gas engines and agricultural engines and implements. These are decked out in gayer colours than is usual in those of British manufacture, and brass casings are common on the agricultural engines, just as the locomotives were at the Paris Exhibition of 1889,—a practice now nearly abandoned in the Vincennes show. For those who take an interest in these departments there is plenty to be seen. Mention, too, must be made of cotton spinning, and weaving machinery, and machinery for leather dressing, of the fine collection of turbines, of woodworking machinery, British, American, and Continental, and the work of the French industrial schools, each of which is full of interest. France is the home of the automobile, and unfettered by any stupid government restrictions, she has gained the lead in the design and manufacture of these cars, to come up with which other makers will have a long stern-chase. The exhibits are marked by much elegance, taste, and provision for comfort. To all present appearances the oil engine occupies the most important place as a propelling force.

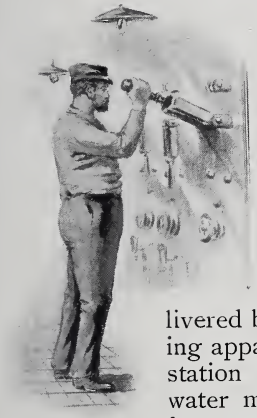
The Civil Engineering section in the gallery, though not frequented by the general public, has very much of interest to the professional man, in the fine collection of models shown, of drawings and photographs of public works, and the appliances used in their construction. It seems to the writer that the French engineers are in no respect behind others in construction of appliances for harbour work, for block-setting, for bridge building, and transportation.

The foregoing summarises the leading features of the Exhibition as they impressed the writer. To the question of whether the Exhibition is worth going to see, the reply is that no engineer can afford to miss such an opportunity of studying the present state of manufactures among the industrial nations. I pass by the architectural beauties, of the illuminations, the popular side of the Exhibition. The engineer must take but a passing glance at these, or neglect them altogether, if the time of his visit is limited to two or three weeks.

ELECTRIC CABLES FOR HIGH-TENSION SERVICE

HOW THEY ARE MADE AND TESTED IN THE UNITED STATES

By William Maver, Jr.



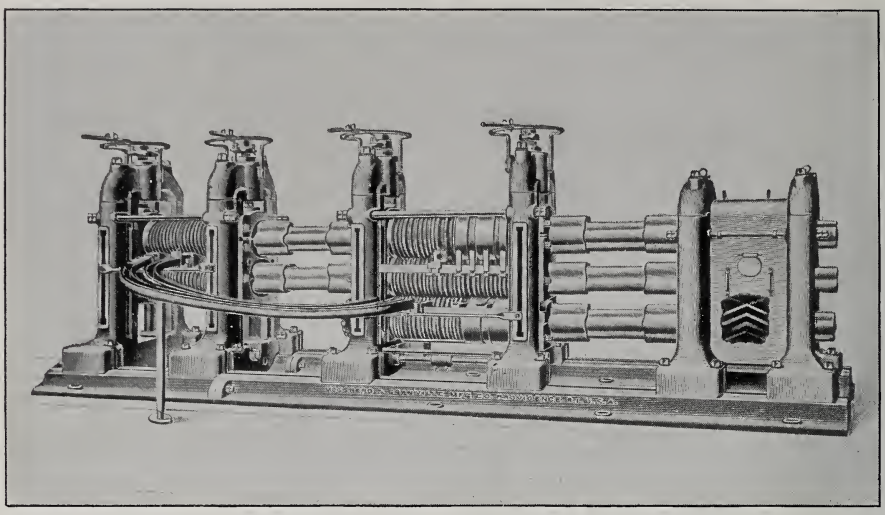
THERE has been a marked tendency in recent years towards the localisation of the central stations of electric light and traction companies at points adjacent to the water side, or the railways, especially the former, where fuel may be delivered by suitable coal conveying apparatus from vessels to the station coal bins, and where water may be cheaply obtained for condensing, and also where generators of large and uniform units, capable of being operated at most efficient loads, may be employed. The cost of coal hauling in American cities is estimated at about fifty cents per ton, and the importance of this item alone will be appreciated when it is considered that some of the large new power houses in the city of New York will ultimately use approximately 175,000 tons of coal per annum.

In addition to these sources of economies there are also to be considered the concentration of executive and operating forces in one building, and the releasing of valuable real estate in the busy and crowded sections of cities. In the old portion of New York City alone, south of the Harlem River, when the plans now in process of execution shall have been completed, the output of eight power stations, situated at different points, will be generated and transmitted from one large central station on the East River. The large electric traction companies of Manhattan will also soon have their power houses at one or two points on the river side, where a plant capable of generating about 60,000 kilowatts, or about 80,000 horse-power, is now being completed.

It is generally well known, perhaps, that the centralisation of such power stations is made commercially practicable by the transmission at a high electrical pressure of the electrical energy generated at the central stations to the points of distribution,—it may be three, five, or ten miles distant,—the pressures ranging in New York City from 6600 to about 8000 volts. This electrical energy is successfully transmitted through cables in the underground electric subways, and on many of the circuits electrical energy to the amount of from 1000 to 2000 kilowatts (say, 1340 to 2680 mechanical horse power) is thus transmitted.

When not much more than a decade ago the order was promulgated to place underground the 2400-volt electric light circuits of New York, the order was proclaimed by the companies concerned and by many experts and contractors to be entirely impracticable. The maximum electrical energy transmitted over such circuits did not, at that time, much exceed 100 kilowatts. But despite the adverse predictions, the circuits were successfully operated in cables underground.

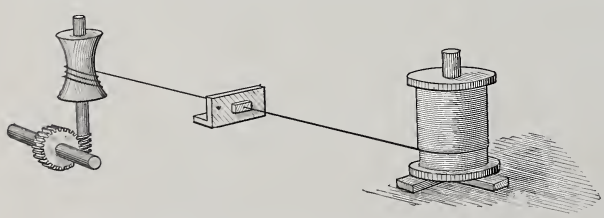
It is apparent that the vastly greater quantities of electrical energy now transmitted at a five-fold higher pressure than was first employed must have necessitated the employment of a cable of considerably improved construction, and it is thought that a description of some of the processes of manufacture of these cables may be of interest. Two types of underground cables are now used in the United States for this pur-



A SET OF "BREAKING-DOWN" ROLLS FOR MAKING COPPER WIRE

pose, namely, rubber and paper, or fibre, cables. These names relate to the insulating material with which the conductors of the cables are covered.

The metal used for the conductors of underground electric cables is copper. Practically the only rival of copper for electrical purposes, outside of iron for overhead telegraph lines, is aluminium. This rivalry, however, extends only to overhead wires where the matter of diameter of the wire is not very material, the diameter of an aluminium wire being 1.27 times greater than that of a copper wire of equal conductivity. The weight of an aluminium wire, on the other hand, is one-half that of a copper wire of equal conductivity. At the present price of aluminium, which is slightly less than one-half that of copper, it would, therefore, be economical to use aluminium wire for overhead purposes, and this has been done recently in several instances. For underground purposes, however, it would seem that the greater diameter of the aluminium wire for a given conductivity must place it at a disadvantage, as compared with copper, on account of the greater amount of insulating material and lead required to cover the aluminium wire. The increased space that the latter wire would occupy in the underground ducts, where space is often quite a serious consideration, is also a disadvantage.



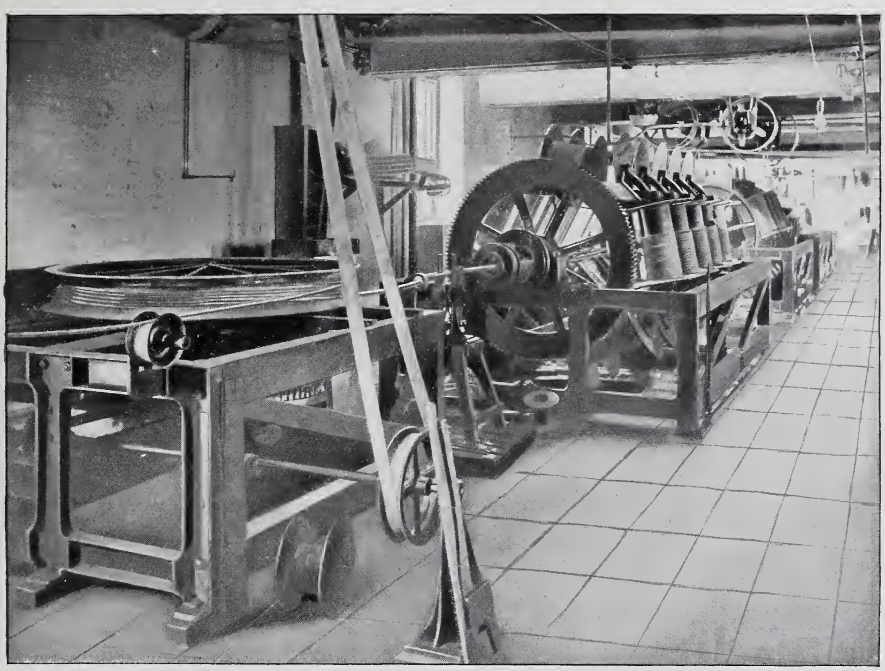
DIAGRAMMATIC ILLUSTRATION OF WIRE DRAWING

The term electric cable includes the conductor, the insulating material, and the armour, or lead covering, as well as any jute or taping that may be added. The process of manufacture of the cable may be taken up at the wire factory, where the copper is received in billets, or ingots, weighing about 200 pounds. The billets are first rolled into rods by rolling machines or mills, shown on this page. The ingots while red hot are passed through roll after roll, the rolls gradually reducing the wire to a desired size. In the first stages the rods are passed back and forth by men on each side of the mills, but as the rod increases in length and diminishes in diameter, it is passed from one

set of rolls to another by the curved guides, shown in the cut. These rolls will break down fifty tons of copper per day of ten hours from the ingot to a rod or wire equal to No. 5 B and S gauge (No. 7 Birmingham gauge).

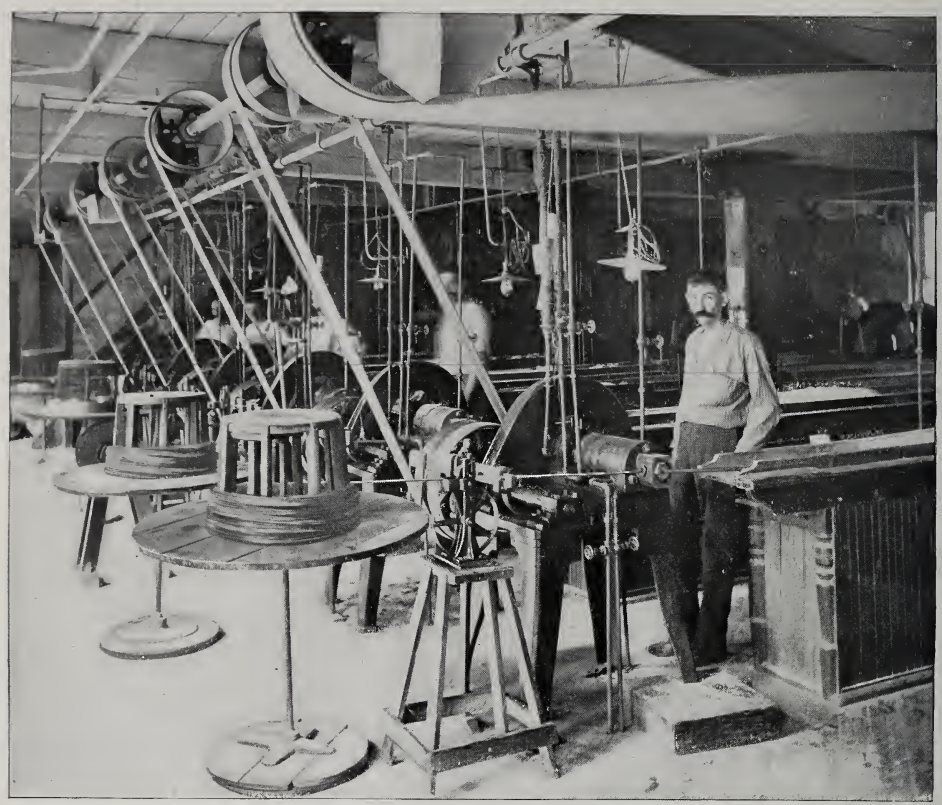
This process, however, does not leave the wire as uniformly round as desired; hence the rods are usually subjected to a "drawing" process, which consists in drawing the wire, while cold, by means of suitable machinery, through dies of hardened steel. It is usually necessary to repeat this drawing process several times with dies of gradually diminishing diameter, until the desired gauge of wire is finally reached. The drawing process hardens the wire and also materially increases its strength; at the same time it renders the wire less pliable. The strength of the copper wire thus hardened appears to rest very largely in a thin shell formed by the drawing process, for when the shell is nicked, even if only very slightly, the wire breaks readily at that point. Before each drawing the wire is covered with flour paste, baked on the wire in an oven. This acts as a lubricant while the wire is passing through the die.

When the wire has been drawn to the desired size, it is annealed to the required degree of softness and pliability, by heating, the extent of the annealing depending upon the use for which the wire is designed. For the conductors used for overhead telegraph and telephone purposes, it is not annealed after the final drawing, or but very slightly, and this wire is termed "hard-drawn." But for larger wires, such as No. 00 or No. 0000 B. and S. gauge (equal to 0.364 and 0.460-inch diameter, respectively), the wire is always "soft"-drawn. The wire used in cables is always soft-drawn, regardless of the size, to insure flexibility.



A WIRE STRANDING MACHINE

The wire being thus reduced to the desired diameter, the treatment which it will next undergo will depend on the nature of the insulating material with which it is to be covered. If a rubbe



A SET OF INSULATING MACHINES

compound is to be used, the wire will be tinned, it being supposed that this is a protection against any possible deleterious effects of the sulphur used in vulcanising the rubber. The tinning is effected by passing the wire through a vat of molten tin. When the insulating material is fibre or paper, the wire is not tinned.

The wire is now practically ready for use in the cable. There is, however, another matter to be considered first; that is, whether the conductor of the cable is to be "solid" or stranded. When the diameter of the conductor does not exceed 0.257 inch diameter (No. 2 B and S gauge), the conductor is usually solid; that is, it consists of one wire. Above this size the conductor is stranded, chiefly to obtain greater flexibility of the cable. When all the wires to be used in a strand are of like diameter, the number of wires necessary to be used to complete a uniform strand is readily calculated. The central wire of a strand is held straight. Around this six similar wires are laid, spirally. For the next layer of the strand twelve wires are required; for the third layer eighteen wires are neces-

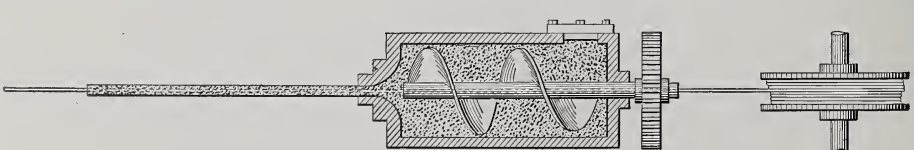


DIAGRAM ILLUSTRATING THE OPERATION OF AN INSULATING MACHINE

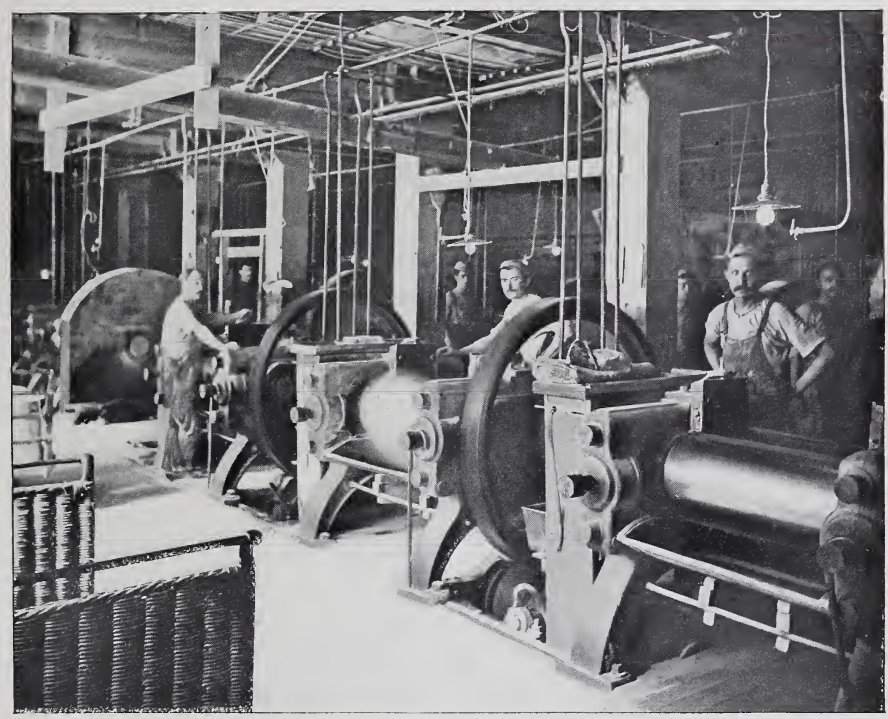
sary; and for each additional layer six wires are added. If it is desired to have four layers around the central wire, sixty-one wires will compose the strand. If also it is desired that the stranded conductor shall be the equivalent of a solid wire, say, 0.500 inch in diameter, it is spoken of as a wire of 250,000 circular mils. This is the square of the diameter of the conductor in thousandths of an inch. The size of the wires of such a strand is then calculated by taking the quotient of 61 into 250,000, which gives the diameter of these wires in circular mils. The square root of this quotient gives the diameter of the wires of the strand in mils. Or this is expressed by the formula:—

$$\sqrt{\frac{250,000}{61}}$$

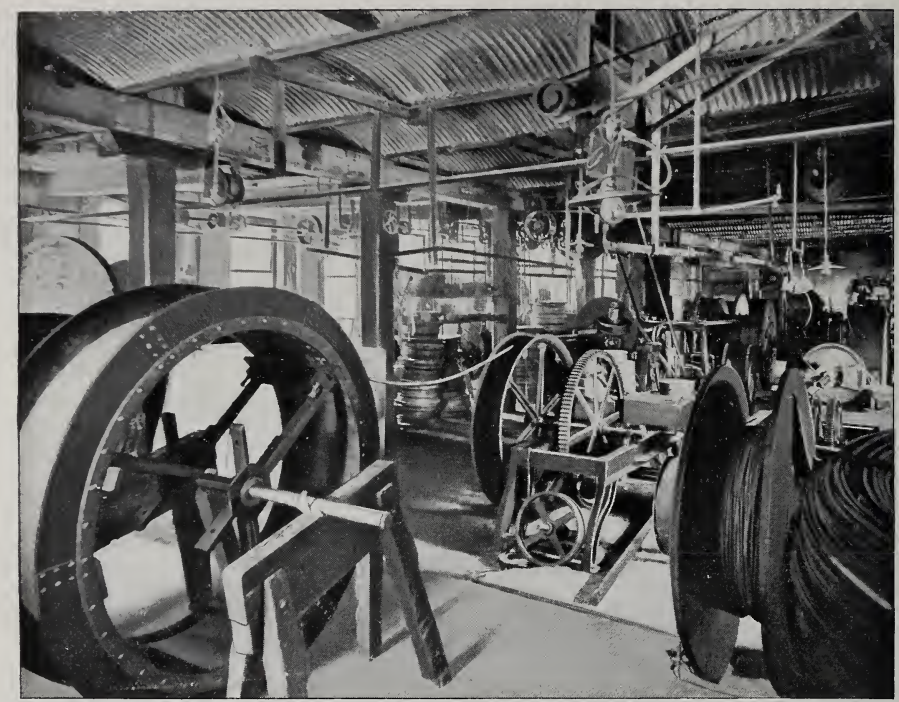
The work of stranding the wire is usually done in one process by a stranding machine, like that shown on page 469. The wires of the strand are wound on reels, which are placed on suitable spindles, on frames around the machine, the reels for each layer of wires being in the same circle. The circle of reels for each layer is, of course, placed a suitable distance behind or before its neighbouring circle, the reels for the larger layers being, naturally, behind those of the smaller.

The centre wire of the strand passes from its reel, which is stationary in one place, and is held taut by a take-up drum or reel. The wires of the first layer are wound around this wire, and the wires of the second layer are wound snugly around the first layer, and so on, the reels of contiguous layers of wire being caused to revolve with their respective frames, in opposite directions, which gives the respective layers of the strand a right and left-hand lay.

Machines for such work may be designed to carry 130 reels of wire, weigh-



IN THE MIXING ROOM



A TAPING MACHINE

ing 1000 pounds each. The machine illustrated carries sixty-one reels. For the class of work here considered, however, the stranding machine need not ordinarily require more than fifty reels of wire for the strand, inasmuch as it follows from well-known electrical laws that the higher the electromotive force or voltage employed, the smaller may be the cross-section of the conductor for the transmission of a given amount of power. Thus, if the voltage of a circuit be doubled, the cross-section or weight of the conductor may be reduced one-fourth without increasing the percentage of loss in transmission. An arithmetical example of this may be given. Assume that it is desired to transmit over a given circuit, say, one mile in length, 3000 kilowatts or electrical horse-power, equal to 4020 mechanical horse-power, the electromotive force being 6000 volts. In this case the current strength will be 500 ampères, since 6000 volts × 500 ampères = 3000 kilowatts. If the loss is to be, say, 10 per cent., or 600 volts, in one mile of conductors, the resistance of the wire should be 1.2 ohm per mile, which would require a copper wire weighing about 726 pounds per mile. If it be desired to increase the electrical pressure to 12,000 volts, the same electrical energy may be transmitted with a current of 250 ampères, in which case the 10 per cent. loss will be 1200 volts for the same length of wire. This allows the use of a wire having a resistance of 4.8 ohms per mile, for which a wire weighing 181 pounds per mile will suffice.

The completed strand, as it passes from the machine, is wound on a reel or drum, and is then ready to receive its covering of insulating material.

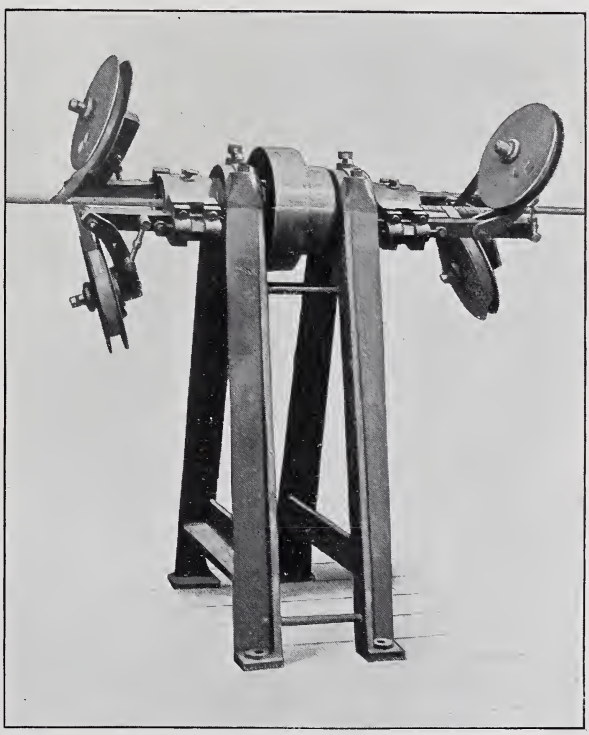
As previously remarked, the insulating material of high-tension cables is now either a rubber compound, or paper saturated with a resinous oil. Gutta-percha, which has been used so extensively,—in fact, it may be said, exclusively, up to this time,—as the insulating

material for long submarine cables, is not used at all for high or low-tension cables in cities, its low melting point, about 120° F., being fatal to its employment for such purposes, inasmuch as this temperature is frequently encountered in city streets. Indeed, a temporary overload of a conductor might raise the temperature to this point, in which event the conductor would settle to the lead armour or sheathing of the cable, thereby, of course, ending its usefulness.

The pure rubber used in the rubber compounds employed as an insulating material is brought to the factory in balls, which weigh from five to sixty pounds. While this is termed "pure rubber," it is quite impure in a strict sense, and during the purifying process it undergoes a shrinkage of about 20 per cent. The first step in its preparation consists in soaking it for about twelve hours in water at a temperature of about 200 or 212 degrees F. After undergoing this boiling process, the ball is passed through corrugated rolls, or mills, by which the rubber is pressed into a thin, rough sheet, about the size of a sheep's hide. As the rubber is thus passed and repassed through this mill, streams of water are caused to fall upon it, washing away the impurities which the roller exposes. After the sheets have been thoroughly washed, they are taken to a drying room, where they are usually kept for two, three, or more weeks.

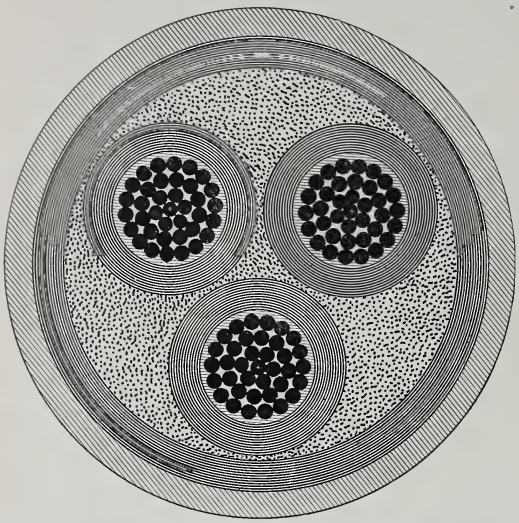
The sheets are then taken to the "break-down" mills, where they are passed repeatedly through rollers which are kept at a temperature of about 200° F. This reduces the sheet to a homogeneous, plastic mass of pure rubber. The rubber is then folded into thick sheets and passed into the mixing room, shown on page 471. Here, as the pure rubber is passed time after time between the rolls, the attendants add the ingredients, which make the completed compound, in such proportions as may be deemed advisable for any particular case, the proportion of such added ingredients, or adulterants, and pure rubber varying with every manufacturer. A sheet of the pure rubber, ready for the mixer, is shown on the nearest mill in the illustration.

The ingredients composing a well-known rubber compound are as follows: —15 pounds Para rubber, 4.5 pounds litharge, 6 pounds whiting, 4.5 pounds blue lead, 7 ounces sulphur. The amount of pure rubber used in the better classes of cable varies from 35 to 50 per cent. The various ingredients are added gradually to the rubber during the process of mixing, which requires for its proper operation a high grade of



A PAPER COVERING MACHINE

shop skill. The mills are kept at a temperature of about 200° F. during the process. In the mixing room of one large manufacturing company 6000



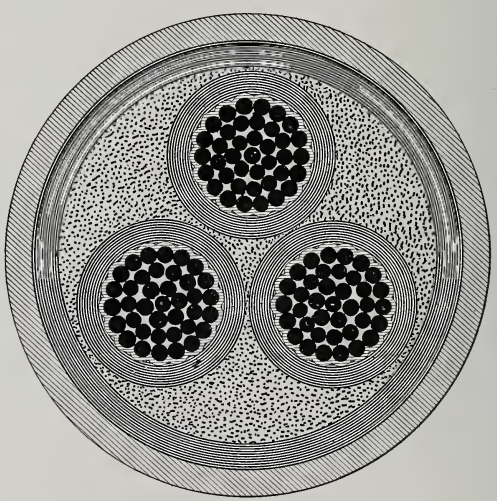
A JACKETED 7000 TO 10,000 VOLT PAPER CABLE

pounds of the insulating compound are prepared in a day of ten hours.

When thoroughly mixed, the rubber compound is ready for placing over the wire. This is done in two general ways,—first, by the use of insulating machines somewhat similar to the machines used in making rubber tubing. In the second method the compound is formed into a strip which is placed over the conductor. In the latter process the wire is rolled off a drum, or reel, and passes through a guide to and between a pair of grooved wheels, where the rubber strip is lapped closely around the wire, the pressure causing the edges of the strips to adhere, and at the same time the surplus rubber is removed by suitable cutting edges on the grooved wheels. This produces a seam in the insulation.

The insulating machines used in the first-named method are shown on page 470. Here the prepared compound is fed by an attendant into an opening in the machine; a worm draws the compound towards the die through which the wire is passing, as shown in the theoretical diagram on the same page, and the wire is covered with the compound to the thickness desired, this being regulated by the excess of diameter of the die over the diameter of the wire.

The compound is maintained in the desired plastic condition while in the machine by suitably arranged water jackets, the temperature of which is governed by valves which admit steam or cold water. The rate at which the wire may be covered in this way depends largely on the size of the wire and the thickness of the covering, which is termed the "wall." This method produces what is termed a "seamless" insulation. The wire, while being drawn through the die, is held by guides directly in the centre of the die to ensure an equal distribution or centering of the compound over the surface of the wire. The conductor, after issuing, covered, from the insulating machine, is drawn along a table through powdered



A JACKETED 7000 TO 10,000-VOLT RUBBER CABLE

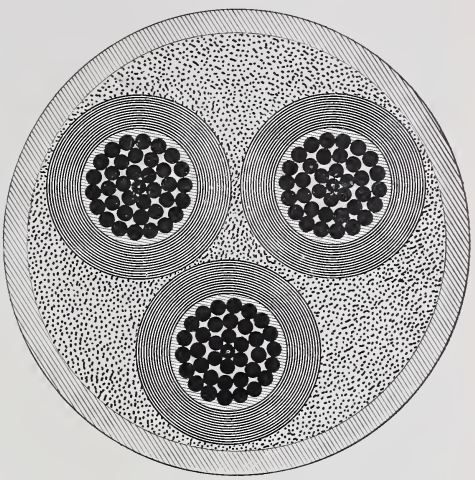
talc, a distance of 40 or 50 feet, to a drum, upon which it is carefully coiled. The wire thus covered may then be taped prior to vulcanising, or it may

be vulcanised without taping, but in the largest sizes of cables it is customary to first tape the insulated wire.

The taping machinery is shown on page 472. The taping apparatus proper is in the centre of the picture. It consists of a revolving disc on the face of which a reel holding the tape is suitably supported. The insulated wire, or cable, passes through a sleeve in the centre of the disc, and as it does, the reel, in the act of revolving with the disc, wraps the tape spirally around the cable. The latter passes from the iron take-up drum, shown in the foreground, to a reel and is then ready for vulcanising. The process of vulcanising the compound consists in placing the wire and reel in an oven, where it is subjected to a steam or dry heat at a temperature of 250° F. to 300° F. Steam heat is preferred by many manufacturers as giving the best results. Much care is required in the process, and the most favourable temperature and the length of time required to bring the compound to the desired degree of hardness and tenacity are matters of experiment. They vary with different compounds.

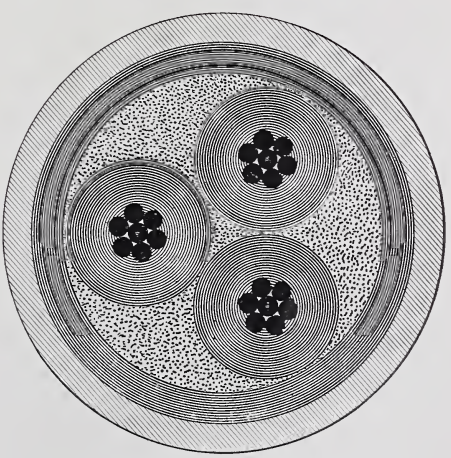
At this point the manufacture of paper-covered cables may be considered. This consists essentially of winding strips of manila paper in reversed layers to any desired thickness over the conductor by a machine like that shown on page 473. When the conductor is covered it is wound on a suitable reel which, with the conductor, is placed in a "bake" oven, where it is subjected for hours to a temperature sufficiently high to drive all the atmospheric moisture out of the paper. The oven in which this baking is done is tightly sealed, except at a vent at the top. An attendant, by holding his hand above this orifice, is able to tell when the drying has proceeded sufficiently far by the nature of the air which passes out. After proper drying, the reel and conductor are immersed in a vat of boiling resin oil, often termed London oil, and as the baking process has rendered the paper exceedingly hygroscopic, it absorbs the oil with avidity.

Formerly the paper was placed over the wire as tightly as possible, but this plan has been abandoned for several reasons, one of them being that it imparted too great rigidity to the com-



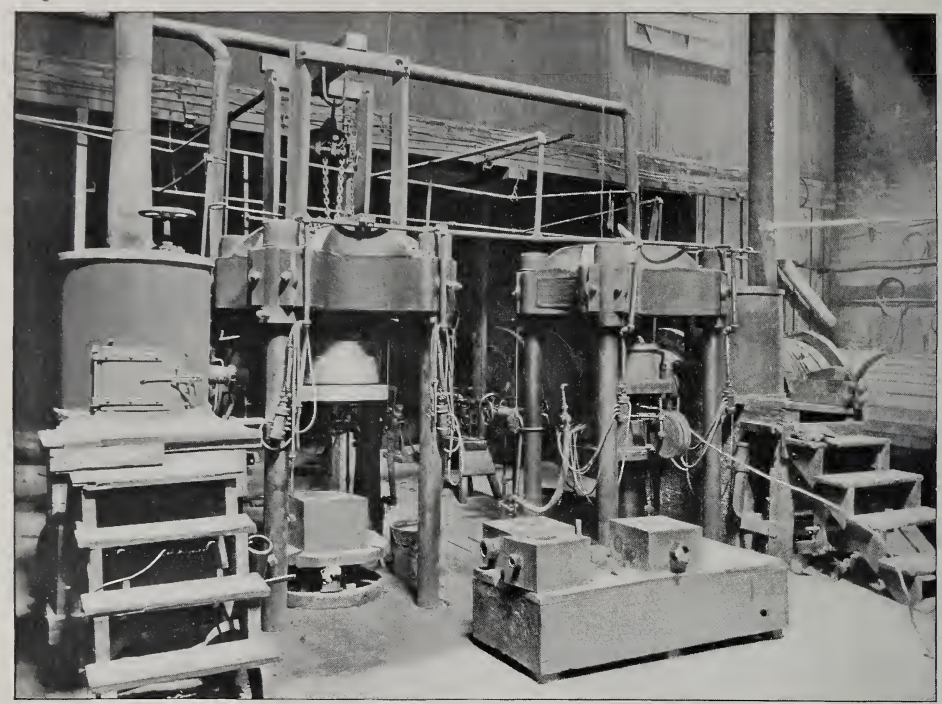
UNJACKETED 7000-VOLT RUBBER CABLE

pleted cable, with the result that the cable could not be bent without breaking the insulation. Further, it retarded the heat in the bake oven from reaching into the inner layers of the paper to such an extent that the outer layers



JACKETED 25,000-VOLT RUBBER CABLE

were injured by too long exposure to the heat of the oven. Again, when the paper was put on under strong pressure, the compound could not readily pene-



LEAD PRESSES FOR SHEATHING CABLES

trate to the inner coils, and as the ability of such cables to resist high electrical pressure is largely due to the presence of the oil, the importance of this latter point is obvious. By placing the paper layers more loosely over the conductor, the layers slip easily over one another when the cable is bent, and the heat and the oil more readily penetrate to the inner layers, thereby improving the insulation resistance and increasing the pressure-resisting quality of the covering.

The conductors thus insulated are now ready for bunching into cable form. For the high-tension cables here particularly referred to, three insulated conductors are usually employed. These are laid up in a strand, or spirally, and are taped, the interstices being filled in with jute, after which the conductors are ready for lead-covering. In other instances the conductors are bunched, and a "jacket" of paper strips or rubber compound, as the case may be, is put around the conductors thus bunched. This latter method is sometimes termed "split" insulation, because of the fact that the insulation is divided between the jacket and the insulation over each conductor. Examples of such conductors, with and without this split insulation, are shown in the diagrams on pages 474 and 475.

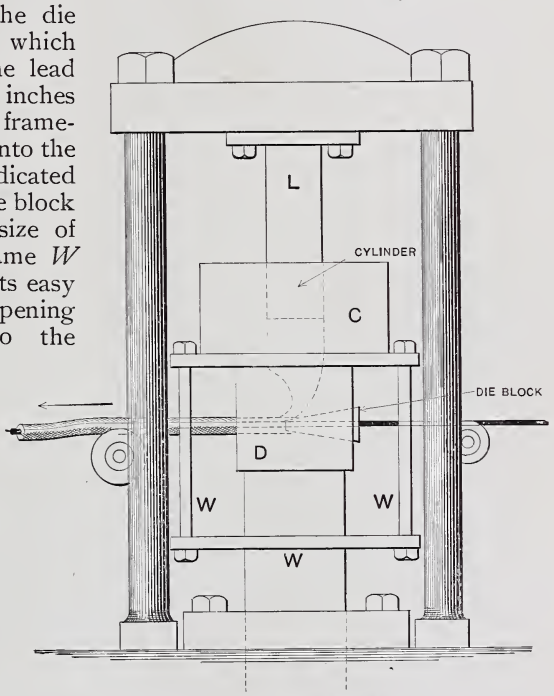
All cables intended for use in underground conduits in cities are now lead-covered to protect the insulating material from destruction by the acids, alkalies, etc., found in such conduits. In the case of paper or fibre cables it is absolutely necessary that they be covered with lead to protect them from moisture in the underground conduits. Rubber cables are, of course, moisture-proof, and if nothing but water were to be encountered in the conduits they would not require to be lead-covered. Rubber immersed in salt or fresh water appears to be imperishable, barring mechanical injury.

The lead-covering of the cable is an interesting process. The illustration on

the page opposite shows the appearance of a vertical type of lead-covering machine, in which the lead is put on hot. The framework and the other parts of this machine are of massive construction to withstand the heavy pressure which is applied in putting on the lead casing. The pillars of the frame are of solid iron, about 10 inches in diameter. The working parts of the machine are a solid iron ram, about 15 inches in diameter, operated by hydraulic pressure. The ram passes down several feet into a vault in the ground, the hydraulic pressure being applied at the lower end. In the diagram on this page *D* is the die block, *C* a hollow cylinder into which molten lead is poured; *L* is the lead ram, or plunger, of solid iron, 5 inches in diameter, rigidly bolted to the framework. Its lower end fits snugly into the receptacle in the cylinder *C*, as indicated by the dotted lines. As the die block must be changed to suit the size of cable to be lead-covered, the frame *W W W* is provided to permit of its easy removal. There is a curved opening in the die block, which reachesto the guide through which the cable is seen to pass. The die block rests on the top of the lower ram and the cylinder *C* rests on *D*, in which respective positions they are held by bolts.

In preparing the lead and machine for the operation of lead-covering the insulation, the operation is practically as follows: — The hydraulic ram is dropped down, and carries the die block and cylinder with it, with drawing the cylinder from the lead plunger *L*, which is stationary. The cylinder is then filled with molten lead, which is termed a "charge." As it is not desirable to place the lead in a melted state over the insulation, the charge is allowed to chill somewhat before the operation of covering is begun. The time for this varies with the size of the cable, and may be from three to four minutes. To prevent undue chilling of the lead, gas jets are placed around the cylinder. At the proper time hydraulic pressure is slowly applied to the ram. The pressure exerted on the end of this ram, which, in some cases, amounts to 500 tons, causes the cylinder to rise up against the plunger with the result that the lead is pressed down into the die, forming a tube or casing around the insulated conductor. At the same time, by suitable take-up reels, the cable is drawn through the die block. In other types of lead-covering machines the hydraulic pressure is applied from the top.

The lead is frequently alloyed with a small percentage of tin, about 2 per cent. This was done originally to protect the lead from the attack of acids, etc., but its utility in this respect is questionable. The tin, however, adds a certain amount of rigidity to the cable which is useful in facilitating the operation of drawing it into the underground ducts. The tin, at the same time, adds a difficulty to the process of lead-covering the cable, the small percentage above mentioned almost doubling the pressure that would be required to put on the lead pure. The rate at which the



ELEVATION OF A LEAD PRESS

cable may be lead-covered depends largely on the size of the cable, ranging from a few feet per minute in the case of large cables to several hundred feet per minute for the smaller cables.

The cable is now practically ready for drawing into the underground ducts. Some of the manufacturers of high-tension cables, however, first subject them to a severe breaking-down, or puncture test, by applying an electrical pressure from one and a half to three or four times the pressure to which the cable will be subjected in actual service. The pressure test varies with the length of time the test is to be applied. Thus, a cable designed to withstand a working pressure of 500 volts may be subjected to a pressure of 2500 volts for one hour, or to 4000 volts for a few moments. If intended to withstand a working pressure of 10,000 volts, it may be subjected to 15,000 volts for one hour or to an instantaneous pressure of 30,000 volts.

The high pressures for these tests are developed by means of an alternating-current generator and step-up transformers. When the apparatus is ready, the wires leading from it are connected to the conductor, and to the lead cover of the cable, respectively. In the case of rubber cables, these tests are sometimes applied before the lead cover is put on, the cable being immersed in a tank of water. The ends of the cable are, of course, kept out of the water. In this latter case, the wires run from the testing machine to the conductor of the cable and to the water in which the cable is immersed. If the cable is defective at any point, or if the pressure is too great for the inherent puncture-resisting quality of the insulating material, the current will "jump" and puncture the cable.

At such high pressures it is obviously essential that much care should be exercised in making these tests. The lead is removed, in the case of rubber cables, for a distance of several inches from the ends of the cable, as, otherwise, when a pressure of 20,000 or 25,000 volts is reached, the electricity will creep along the surface of the insulation (as it may be seen to do also on a sheet of thick glass subjected to high pressures), thereby reducing the tension of the current.

As previously remarked, the maximum electromotive force used in the city of New York on underground cables is about 6600 volts. This is employed by the electric traction and electric lighting companies. The longest circuit on which this pressure is used measures about ten miles, while many other circuits range from one mile to five and six miles in length. As also previously intimated, the maximum electrical energy transmitted over these circuits from the power houses to the various sub-stations or points of distribution ranges from 1300 to 2700 horse-power.

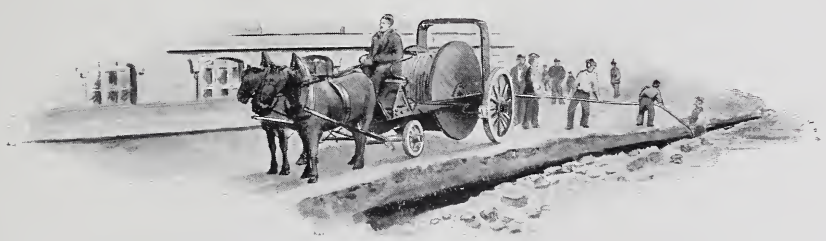
Both rubber and paper cables are employed for this service. These cables are illustrated in cross-section and actual size on pages 474 and 475. The dimensions of one of these cables may be given; for instance, a three-conductor cable, rubber, now operating at 6600 volts. Each conductor is made up of thirty-seven copper wires, giving a total cross-section of 250,000 circular mils, equal to 0.5 inch diameter. The thickness of the rubber insulating wall around each conductor is 5-32 inch. This is a rubber-jacketed, or "split" insulation, cable. The jacket is also 5-32 inch thick. This ensures 10-32 inch of rubber compound between conductors, and between any conductor and the ground. Each conductor, and also the jacket, is covered with a tape, put on spirally outside of the rubber. The lead-covering of this cable is ⅛ inch thick. The outside diameter of the cable is 2.56 inches. The interstices between the conductors are filled in with jute.

The highest working pressure for underground cables thus far proposed is that soon to be operated by a Western company in the United States. This company has an electric plant, driven by water-power, from which the current is to be transmitted at a pressure of 25,000 volts, on overhead wires, a distance of about twenty miles to the city limits. From this point to the point of distribution in the

city the power is to be transmitted through underground cables, at the same pressure, a distance of three miles. One of the cables to be used for this purpose is shown in cross-section on page 475. This cable consists of three conductors, each of No. 2 B and S gauge. The thickness of insulation around each conductor is 7-32 inch, and the thickness of the jacket is 5-32 inch. The cable is lead-covered.

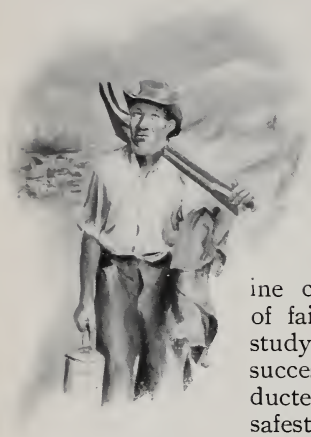
Inasmuch as some authorities consider that 40,000 volts represent the maximum electrical pressure that can be advantageously employed on overhead lines for the transmission of electrical energy on a large scale, it is thought that the safe maximum pressure for underground cables has, perhaps, been reached, if not exceeded, in the installation referred to, owing to the difficulties to be encountered in maintaining the insulation at such high pressures. The operation of this circuit will be watched with much interest, and doubtless by its success or failure the pressure of subsequent installations of a like nature will be measurably gauged

The illustrations of works interiors in this article were reproduced from photographs obtained through the courtesy of the Safety Insulated Wire & Cable Company, of New York.



HOW TO MAKE GOLD DREDGING PAY

By A. W. Robinson, M. Am. Soc. C E., M. Am. Soc, M. E.

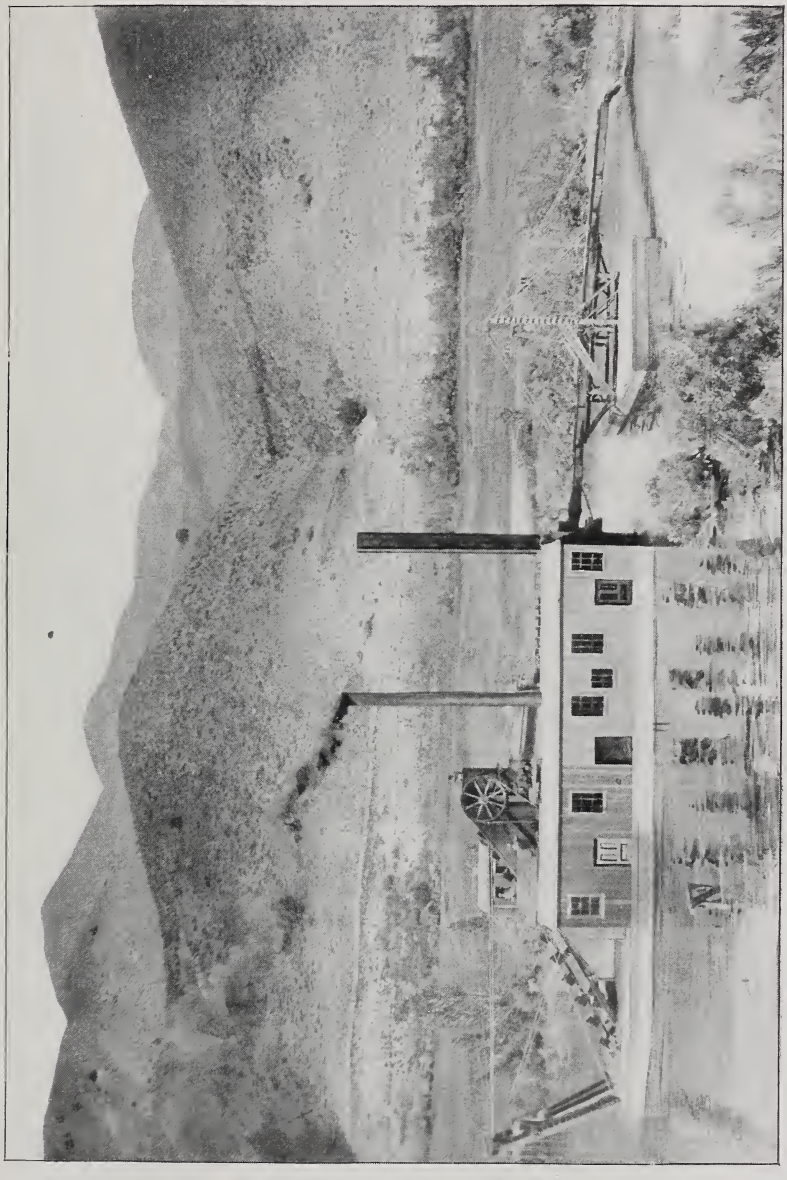


DREDGING for gold seems, at first sight, to be a simple proposition, and yet the numerous failures that have occurred make it necessary to exercise caution and to examine carefully the causes of failure, as well as to study the elements of success. If properly conducted, it is one of the safest forms of mining, for the reason that the ground can be examined, tested, and the probabilities determined beforehand with reasonable accuracy. It then becomes analogous to manufacturing, with the ground as the raw material and the gold as the product. To attain success in manufacturing, a man must be master of his business, must have an ample supply of raw material, and must be able to sell at a proper advance over cost of production. In other words, there must be good men, good material, and good markets, and this may be all summed up in two words, good management. As good management is essential to success in ordinary business affairs, so is it in the business of dredging for gold.

There is this advantage over other forms of manufacturing, in that the product is of uniform fixed value, and always marketable without expense of selling. Every ounce of gold won is that much money to its owner and a permanent addition to the wealth of the world. Gold dredging is, however, analogous to manufacturing in that the cost of production must be less than the value of the product. Given good management, therefore, to begin with, the two cardinal points to be determined are, first, the value and extent of the ground, and second, the cost of working it. The success of the whole enterprise depends on the correct determination of these two questions.

As to the first point, namely, the value and extent of the ground, a thorough examination should be made by a person possessing the necessary ability and experience, and who is able to draw sound conclusions from his observations. This is not work for a young college graduate, nor yet for the so-called practical miner, although both may render efficient help. Still less is it the business of men in other walks of life, who, thirsting for riches, turn to gold mining, expecting an immediate fortune. His opinion will be safest who has had not only the wide experience in all lines connected with his work, but who has likewise the honesty of purpose and soundness of judgment to avoid deceiving himself or his clients, and who can determine whether or not the proposition has in it the elements of financial success.

Many men whose opinions are trustworthy on other subjects are entirely unable to form a sane or just conclusion on matters connected with gold. Many, if not most, men also are inclined to put a better face on the question than usually exists, and the sight of a few yellow colours leads them at once to figure out a bonanza. If investors would only bring to bear on gold mining the same prudence and business sense which is necessary in any other business, it would greatly reduce the number of failures. The same care should be exercised in preparing a full statement of all facts and figures bearing on the case, as in



A TYPICAL GOLD DREDGE

any carefully thought-out manufacturing enterprise. How often do we see the opinions of cheap and incompetent men accepted instead of carefully ascertained facts.

The business of legitimate mining and dredging for gold has suffered much from the evil reputation occasioned by the failure of many schemes that ought never to have been entered upon. Had a competent engineer been consulted, many of these enterprises would never have been begun, or at least would have been carried on in a very different manner. The investor has to guard against two classes of evil advice. One is that of the professional swindler who "promotes" the property for the sole purpose of transmitting the funds of the subscribers into his own pocket, and the other is the well-meaning man who perhaps has a fairly good thing if properly worked, but who has more self-confidence than experience and skill.

The ground should be surveyed,—if not accurately at least approximately,—and a map prepared on which may be recorded the positions of the test-pits, the area available, and the extent of the ground worked over each season. Test-pits should be sunk at sufficiently frequent intervals to place the nature of the ground beyond conjecture. The examination should show the full depth of the gravel, the nature of the bedrock, if any, and the distribution of the values; whether they are greatest at the surface, in layers, or on the bottom. Values are never uniformly distributed, and nothing is more deceptive than a glib statement of so much per cubic yard. It requires the most careful judgment to arrive at a fair average value which will represent the whole.

The nature of the material should also be ascertained, and this not only on the surface. The sizes and percentages of the gravel, from coarsest to finest, should be measured. This is necessary to determine the character of screens to be used, or whether any at all are necessary. The action of the gravel while being washed or sluiced should be experimentally determined. Some gravels wash very freely; others, again, are of a clayey or sticky nature which renders them very difficult to wash. Such gravel requires very careful treatment in order to avoid loss of gold. Other deposits are of a very hard or cemented nature, often with large boulders, which increase the difficulty of working, and, if not fully provided for, failure will ensue.

The condition of water supply is most important. Water is essential to the recovery of gold, and its presence in suitable quantities is a great desideratum. In dredging beds of rivers, the depth, speed of current, fluctuations of level, extent and duration of floods must all be closely observed and their bearing on the proposed enterprise considered. In many rivers the richest pay is found in the "bars," which are shoals or deposits of gravel brought down by the current and formed by slack water. These are frequently dry at low water, and the dredge must, therefore, be able to cut its own flotation into a dry bank.

Gold dredging is not necessarily confined to river beds or natural water courses. Any deposit may be worked with a floating dredge in which the water can be impounded, and a small stream let into the pond in which the dredge is situated, sufficient to supply evaporation and leakage, and to keep the pond clean enough for washing purposes. The same water can be used over and over again in this way, but the dredge must be specially adapted to each case. A dredge which will be suitable for a river channel may not do the work at all in an enclosed piece of ground, and *vice versa*.

The disposition of tailings is a subject which must be carefully studied. Unless the dredge can get rid of all material passed through without choking or piling up in such a manner as to interrupt its work, it is liable to be stopped, and the entire enterprise brought to a standstill until the difficulty can be remedied. The configuration of the ground, the character of the material, the depth of the water, and the height of ground worked above water, all enter into the question and should be carefully determined.

As to the gold itself, the question is threefold. There are to be considered, first, the character of the gold; second, its value per cubic yard of material handled; third, the best method of saving it. On the satisfactory determination of these points the whole success of the enterprise depends, and here long experience and sound judgment are absolutely necessary. The gold may be fine or coarse, of all degrees, and may be easy to save or difficult to save, and the most effective method of saving it depends upon its character. There is no "new discovery" for gold saving. All known methods depend on one thing for their successful action, namely, the great specific gravity of the gold as compared with gravel. Their separation can be effected only by washing with water, aided sometimes by amalgamation, but the methods of washing are subject to wide variation. There are the two extremes of heavy hydraulic sluicing with large volumes of water, carrying down boulders and everything before it, and the thin film of fine concentrates, requiring delicate adjustment for saving fine gold.

As to the value per cubic yard, this is perhaps the most difficult point on which to obtain a reliable estimate. The difficulty is not so much that it cannot be ascertained, but that men involuntarily exaggerate the findings, and there is an extraordinary inclination to take the best and richest spots as an indication of the whole. The only safe way to do is to wash out a considerable quantity for each test, say not less than a cubic yard, taking care that all the material, boulders and all, is included in the measurement, and carefully weigh the result. A sufficient number of these tests, carefully made, will indicate the average value.

In many places in the United States Chinamen or tramp miners can be found working along banks of streams or on river bars with rocker and pan. Wherever these remain any length of time there is sure to be gold in paying quantities. It may, however, exist only on the surface, for these men cannot work deep.

After all the foregoing points have been settled, there remains the final question,—What will it cost to work the property? This is a broad question, and the answer to it is to be found only by subdividing it into all the points which affect the cost, and making a careful analysis and estimate. These points include (1) transportation; (2) cost of living and wages; (3) cost of fuel; (4) cost of lumber and other material of construction; (5) water supply; (6) character of material; (7) depth of working; (8) study of any special difficulties that may be presented. It is impossible to give any data as to these various points or the general conclusions that may be drawn from them. Each locality will have its own characteristics which may be more or less favourable. The dredge itself will be designed to suit the conditions as they exist and its output and operating expenses estimated. The actual output should not be estimated to be more than half the theoretical, and a liberal allowance should be made for contingencies and repairs. Under favourable conditions dredging can be done for 4 or 5 cents (2 to 2½d.) per cubic yard, or even less, and under difficult and costly conditions the cost may rise to 20 or 30 cents (10d. to 1s. 3d.), or even more.

The dredge itself is a most important factor in the cost of operating, but it is not proposed here to go into the mechanical detail of its construction, as that is a large subject by itself. It is sufficient to say that for all ordinary conditions the elevator or ladder type of dredge has become recognised as the standard. It is usually composed of the following elements:—(1) The dredging machine proper; (2) a revolving screen in which the material is washed and the coarse stones are removed; (3) a centrifugal pump for supplying water to the screen; (4) gold saving tables or sluices; (5) apparatus for disposing of tailings.

All these elements are suitably combined upon a hull with boilers, engines and accessories. It is absolutely essential that the dredge be designed and built by those experienced in such work,

and that every detail should be of ample strength and suitable for the purpose. A great many dredges have been built, and while they are by no means finally perfect, experience has developed their construction along certain lines which have been shown to be the best. This experience has cost large sums of money, and he would be foolish indeed who would undertake to build a dredge out of his own unaided genius, without a thorough knowledge of the work of others in this line. These dredges must, as a rule, work in remote places, and be operated by ordinary labour. It is, therefore, of the first importance that they should be of the simplest possible construction, with every part of ample strength, and not liable to get out of order. The earlier dredges were very deficient in this respect, and if breakdowns and repairs are frequent the profits may be quickly converted into losses.

When a dredge is standing still from breakdown there is a four-fold loss going on,—(1) Interest on investment; (2) cost of replacing the broken part; (3) expenses of crew and administration; and (4) loss of gold that would be gained if running. The first cost of the part that failed is but a trifle to the other losses, and the first cost, therefore, of the entire dredge is of slight importance, provided it is of proper design, well built, and capable of working continuously without breaking down. Some repairs there must inevitably be, owing to the severity of the work and the wear and tear due to handling the material; but a distinction must be made between such natural wear and parts structurally weak which may fail without warning. In a good design not only will all parts subject to natural wear be capable of ready renewal, but all important parts subject to strain will be of the strongest design and have a large factor of safety.

Suppose a dredge is earning $400 (£80) per day, and is delayed 30 days through the breakage of some part not readily replaced. There are $12,000 (£2400) lost, without counting interest, or cost of repairs, or wages. A fraction of that amount, put into better design and better material at the outset, would have been the best possible investment. Steel castings can now be obtained at about twice the cost of iron castings, and should be used wherever possible instead of iron, regardless of the extra cost. Some dredging machines on the market are but cheap affairs, made to sell, not to last, and no care or trouble is taken to adapt them to their work; indeed, the builders of them rarely have that experience in operating and maintaining them that is necessary. A cheap dredge is necessarily a poor one, for the requisite strength and quality cannot be obtained without cost; but, on the other hand, an expensive dredge is not necessarily a good one.

When the cost of fuel is high special attention should be paid to economy of steam in the design of the dredge, such as using compound condensing engines and efficient boilers. If fuel be cheap and abundant and skilled labour high, simple high-pressure engines will answer every purpose. Water-power may also be utilised to good advantage for driving a dredge or series of dredges, employing electric transmission. The perfection of modern electrical apparatus for the generation and transmission of power is such that it is, on the whole, quite as reliable as steam. So far from being more complicated, it is, in fact, simpler, for the substitution of simple electric motors for boilers, pipes, pumps, engines, and valves involves fewer parts and less liability to derangement.

In addition to all the technical and commercial elements which have been touched upon, the financial strength of the company intending to operate is of not less importance. It would be useless here to make recommendations as to amount of capital required, as circumstances are widely different. The funds should, however, be available before beginning, and should be sufficient to meet and overcome any reasonable obstacle or difficulty that may arise. That must be left to the judgment of the business man and the engineer in

taking up each special case. Enough has been said to point out the way and to indicate the lines on which this class of work may be successfully carried on. There are few more promising or more profitable fields of work when carefully administered, and the ground available has as yet scarcely been touched. Unfortunately in many cases large sums of money have been squandered without result because of the lack of knowledge and experience to provide for all the points essential to success. All of these failures can be traced to perfectly preventable causes, and when rightly judged, they serve as landmarks to point the safe way. The success of gold dredging in New Zealand is such that a large business has been built up, with many companies operating and paying good dividends from ground that is by no means rich.

TRANSITION TO ELECTRIC POWER

THE INCREASE OF SHORT-DISTANCE TRANSMISSIONS

By Alton D. Adams

SOME years ago there was in the United States an extensive movement of manufacturers to the natural gas fields. The main object of this migration was the advantages of cheap power and fuel in industrial operation, and it afforded simply one of many illustrations of the general tendency for production to advance along the most effective lines. In the long run industries surely tend toward the most advantageous locations and methods.

Water-powers have long been attractive to manufacturers, and many have come to be great centres of industry. This has been especially true as to large works, or those in which the cost of power is a very important factor. In few cases have a large number of small industries, each deriving its energy from an independent water-wheel, been grouped about a water-power. In spite of some apparent advantages of water-powers, their development proceeded but slowly prior to the introduction of electrical machinery, owing largely to the heavy investment necessary to fit them for use and the smallness of the number of manufacturers for whom they could be made available.

Though the use of electrical machinery on an extensive scale to distribute the energy of falling water dates back little more than a decade, it is safe to say that the greater part of the work done by water-power is now delivered by dynamo equipments. In quite a number of cases the special conditions necessary to warrant very long transmissions seem to exist and they are being carried out. There is little to indicate, however, that these long-distance transmissions will ever be of more than comparatively trifling importance to the manufacturing industries. While long-distance electrical transmissions, in a few instances, have caught the public eye, short-distance transmissions, in a great number of cases, have quietly exerted a wide influence as to centres and methods of production.

Transmission of electric power has seemed advisable to some distant places where fuel is high; transition to electric power has proved economical from many points where fuel is low. In the former case, scattered industries are supplied with power at a comparatively high price; in the latter, large groups of factories receive power at a comparatively low price. Transmission of electric power is seen in the power supply to mining plants in the western districts of the United States,

for example, while transition to electric power is illustrated at Niagara Falls. The concentration of manufactures about Niagara is being duplicated on a smaller scale at many other points where the energy of falling water is distributed through electrical equipment.

It seems hardly possible that a just appreciation of the value of water-powers has been lacking until the last decade, and some other reason must be sought for their present rapid development. The obviously new factor that has been introduced in connection with water-powers is electrical equipment, and it is pertinent to inquire, therefore, in what way it tends to increase their advantages. The development of a great water-power usually involves a heavy investment, and the amount grows larger as the number of, and distance between, points at which wheels are located increases. If a long canal must be built to carry the water to numerous users, and if a large number of small wheels and pits must be provided, the outlay is obviously much more considerable than that for several large wheels grouped together. To make a great water-power available for a number of manufactures and its total use possible, without the aid of electrical equipment, usually involves a much larger first cost than is necessary with such equipment.

With dynamo machinery to distribute the energy, the question to be decided in the selection of each generating unit is not what power each industry will require, but the best size of unit, considering the total amount of water and the probable demands for electric energy. A natural result is the smallest possible first cost for generating machinery. In short, the delivery of all water-power electrically makes the compact and economical arrangement of all hydraulic works and apparatus easy, however widely the users of the energy may be scattered.

With any practicable extension of a purely hydraulic power system the locations for manufactures are very limited in extent. This fact works to the disadvantage of the power enterprise and its patrons in two ways. It may well happen that the mill sites are all occupied by industries that do not consume the entire, or even a large part of the available power, which must thus remain unsold. Even though enough factories can be located on the mill sites to make use of the entire water-power, the limited extent of these sites is sure to give them a rental value that largely offsets any advantage of cheap power rates.

A further disadvantage resulting from the restricted areas of mill sites, in connection with hydraulic plants, is the barrier that exists to the sale of power among various consumers at different hours of the day. As is well known, the energy at many water-powers is available twenty-four hours per day. Most manufacturing plants, however, require power only ten hours per day, so that water during the night goes to waste. Where all of the hydraulic mill sites have been taken, more than one-half of the total energy may be unavailable, though it would be worth large sums to chemical or other industries that use power during the entire day.

Large water-power systems must usually be entirely devoted to the purposes of manufactures on an extensive scale, as it is not considered desirable or practicable to divide water privileges into very small units. A consequence is that manufacturers who require power in only moderate quantities have derived little advantage from the development of purely hydraulic works. In view of the limitations just considered, it is not remarkable that many important water-powers remained unimproved so long, as canals and pipes were the only means for distribution. Whatever the form of energy desired by the patron of a hydraulic power system, be it mechanical work, heat, or electricity, a water-wheel must first be erected and the power thus developed changed to the required form.

With electrical distribution only a small space is necessary for the few large wheels and dynamos that absorb the entire energy of the water. Mill sites, instead of being confined to a little land along the banks of a river or canal, at once expand to include the territory

within five, ten or a greater number of miles of the generating plant. This expansion of service area affects the number and the character of power users. The number of industries is limited only by the water available, and the capacity of each may be either great or small. Since mill sites have come to include all the land within a long radius that is not required for other purposes, the opportunity to buy cheap power has only a slight influence on rents. Almost the entire saving in the cost of power is thus free to be divided between the water company and its patrons.

A distinct feature of electrically distributed water-power is the advantages it offers to manufacturers of small and medium capacity. The consumer of 100 horse-power will probably have to pay somewhat more per unit than the consumer of 1000 horse-power, but the difference in rates will represent only a small fraction of that in cost which would result were a separate water-wheel installed for each case.

One of the most obvious results of electric water-power distribution is the rapid growth in the vicinity of such powers of distinctly manufacturing concerns, whose very existence depends on the cheap rates at which energy is distributed. With free competition, the advantages of cheap power are sure to have an effect in a reduced price for the products. These reduced prices react through a larger demand to hasten the development of industry at the centres of cheap power. Society at large is benefited by the increased rate of return on labour and capital in each particular line, and consumers are benefited by the satisfaction of their desires at lower prices. As in most advances of industry, some have to suffer. In this case manufacturers of similar goods, using more expensive power, are at a disadvantage. Such disadvantage may reduce profits, cause a movement to the cheap power, or drive some out of the business, according to the extent to which manufacturing power enters the price of any particular product.

It is interesting to note that the results with electrically distributed water-power are different from what some have expected. Electric energy, it was claimed, for example, would go great distances to the factories; as a fact, however, the factories have gone great distances to the electric power. Location and other advantages being equal, it is found more economical to move an industry once than to move a large amount of energy to it over a great distance daily. Increase of transmission voltages may reduce, but it cannot eliminate, the costs and losses of electric conductors. For very long transmissions the fixed capital in conductors, pole lines, and the extra machinery necessary for the several transformations bears interest, per delivered unit of energy, that might well cover the entire charge for such unit near the generating plant. In the future, as at present, long-distance transmission of electric power must be the exception for special cases, and transition, to within a few miles at most of cheap sources of energy, the rule for the great majority of industries served.

RECENT AMERICAN STEAM-ENGINE PRACTICE

By James B. Stanwood

AMERICAN steam-engine practice can boast of no very remarkable inventions during the past ten years; yet rapid progress has been made in adapting the old, well-known types of engines to modern conditions.

The familiar types are the throttling-engine, single and double-valve automatic, and the four-valve automatic, whose leading example is the Corliss engine. The two most important conditions which affect them are the higher steam pressure now employed and the greater demands of electrical service. To secure economical benefits with this higher steam pressure these engines have been compounded, tripled, and quadrupled, and to fulfill the greater demands of electrical service more satisfactorily they are now directly connected to electric generators. Greater power is now obtained with this higher steam pressure from a cylinder of the same size in single cylinder engines, but to ensure this, the designs have had to be modified. One modification is sometimes made to advantage in side-crank steam-engines, as follows:—The thickness of the crank-hub is reduced to about two-thirds of the shaft diameter; there are no flanges on the main bearing box, the crank-pins are shorter than their diameters, and they have no collars. All this results in reducing the distance from the end of the main bearing to the centre line of the engine by from 25 to 33 per cent. This secures greater stiffness, and makes the crank-pin less liable to heat under heavy loads.

Another modification, common to most engines, is made by using more material to stiffen the frames and by distributing it more scientifically so as to resist severe strains. A third modification has been made by enlarging the crosshead pins in order to overcome the difficulty of making them work quietly. There is but little tendency for them to heat, yet they are liable to cut and wear, because the slight oscillating movement at these pins prevents thorough lubrication. A fourth modification relates to centre-crank engines, and especially to those whose entire power is delivered through one end of the shaft, as in direct connected electrical practice. In consequence of the bitter experiences of sprung shafts, hot bearings and pins, it has been necessary to enlarge the shafts to nearly the diameter of those used in side-crank engines of corresponding size.

The mechanical advantages of two main bearings only for an engine are obvious, as the strains due to imperfect alignment are but slight, and there is no danger from defects in shaft forgings, on account of the simple form of the shaft itself. This form of construction is peculiarly American, and is used in the large cross-compound engines now built directly connected to enormous generators of electricity. Some are made to develop from 4000 to 5000

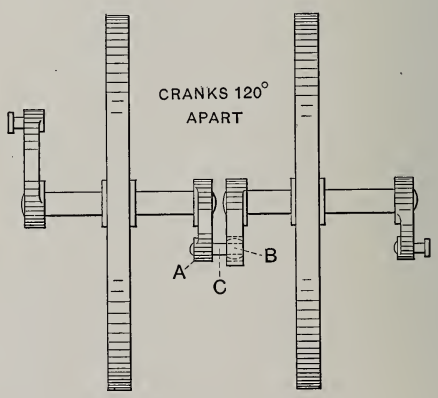


FIG. I.—DRAG CRANK CONSTRUCTION

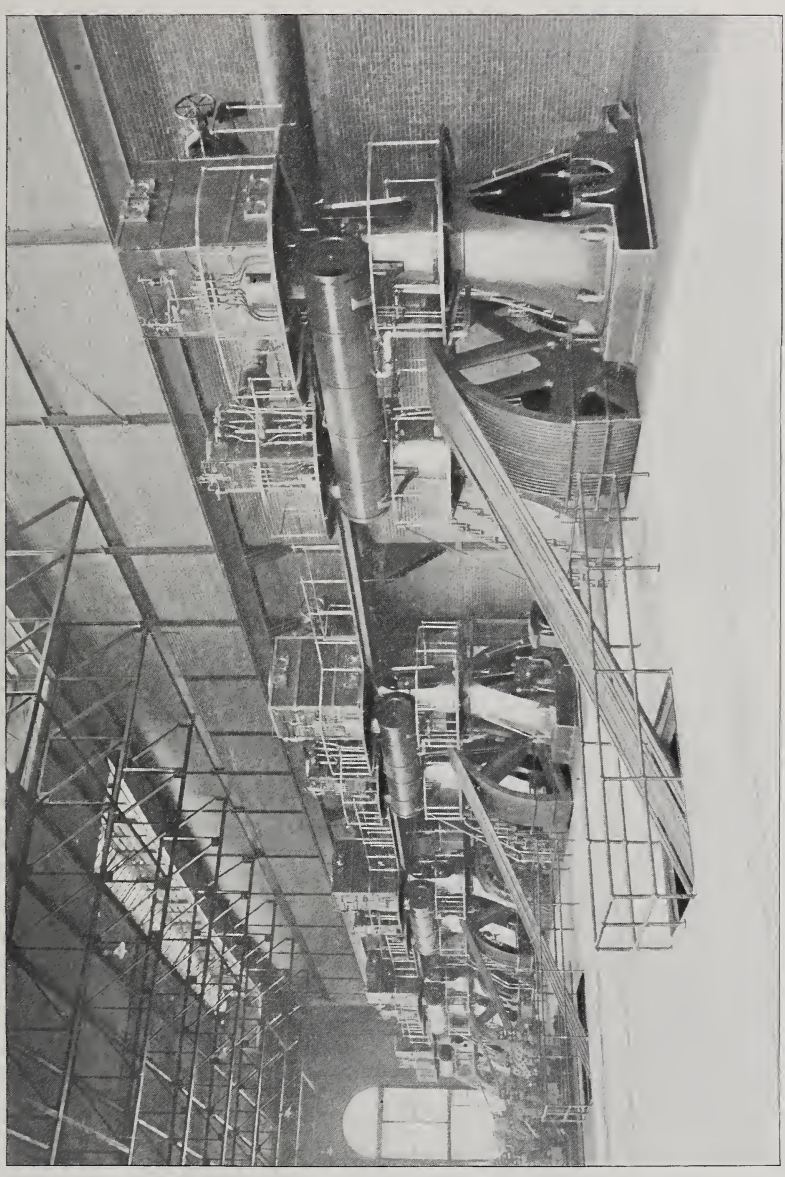


FIG. 2.—VERTICAL CROSS-COMPOUND ENGINES AT THE WORKS OF THE CINCINNATI EDISON ELECTRIC CO., ARRANGED FOR GENERATORS TO BE CARRIED ON EXTENDED SHAFTS ON EACH SIDE OF ENGINES. BUILT BY THE EDWARD P. ALLIS CO., MILWAUKEE, WIS.

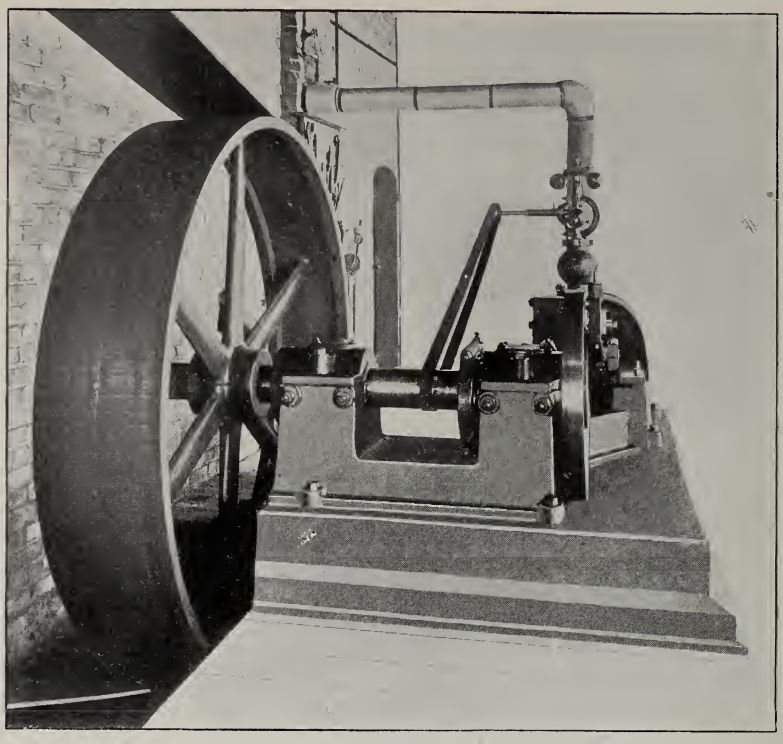


FIG. 3.—A SELF-CONTAINED ENGINE BUILT BY MESSRS. HOUSTON, STANWOOD & GAMBLE, CINCINNATI, OHIO

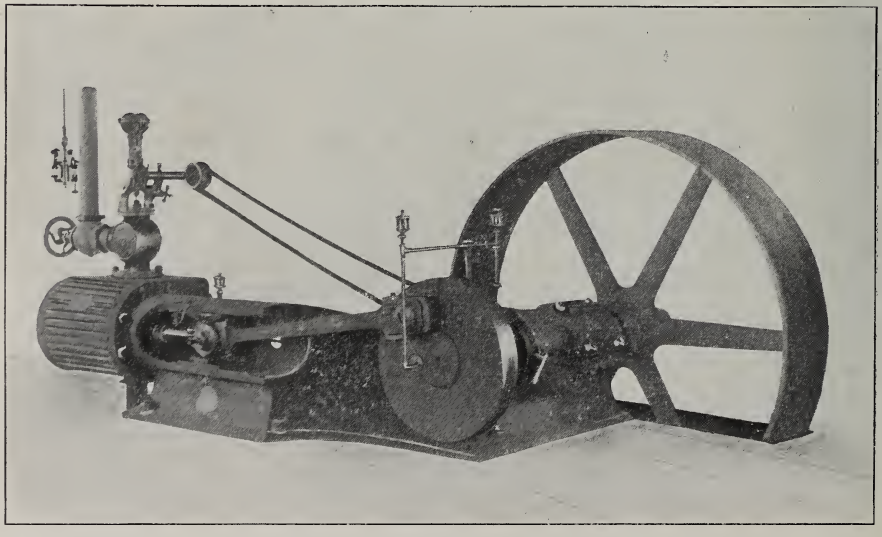
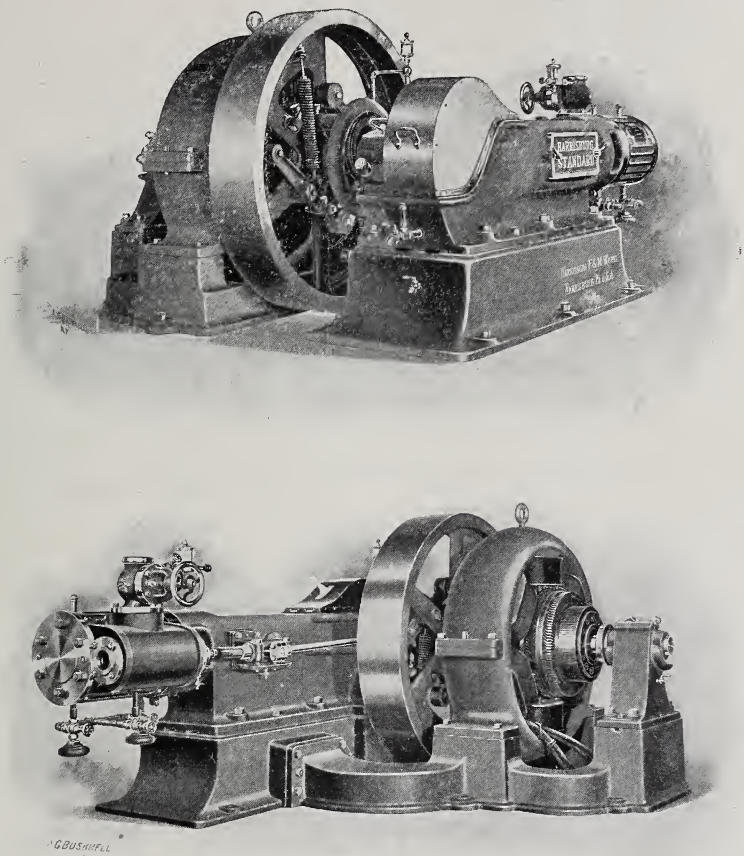


FIG. 4.—A SELF-CONTAINED ENGINE BUILT BY THE CHANDLER & TAYLOR CO., INDIANAPOLIS, IND.

horse-power, and these larger sizes are usually of the vertical type. To accommodate the heavy fly-wheels and armatures the main shafts are necessarily long, and must be large in diameter to prevent excessive deflection; and to sustain this enormous weight the bearings, besides being of large diameter, are proportionally long.



FIGS. 5 AND 6.—SINGLE-VALVE AUTOMATIC ENGINE BUILT BY THE HARRISBURG FOUNDRY AND MACHINE WORKS, HARRISBURG, PA.

The usual type of triple-expansion, high-duty pumping engines is designed to secure this form of shaft construction, as shown in Fig. 1. In this case the crank-pin *C* is secured by hydraulic pressure to the crank-arm *A;* it also works in a sliding ball-joint box in the crank-arm *B*, thus making of it a drag-crank. Also, the E. P. Allis Company, of Milwaukee, have designed some vertical, compound, direct-connected engines, shown in Fig. 2, with the main engine shaft supported by two main bearings only, carrying a grooved fly-wheel over which runs a rope belt, transmitting power for operating arc-lighting machines. Two generators, supported on two separate shafts, one at each end of the main engine shaft, are driven by a drag-crank connection, similar to that just explained.

The only throttling engine used to any extent in America is the simple slide-valve engine, and it has undergone few changes in the last decade, except those in common with other types. The side-crank, self-contained throttling en-

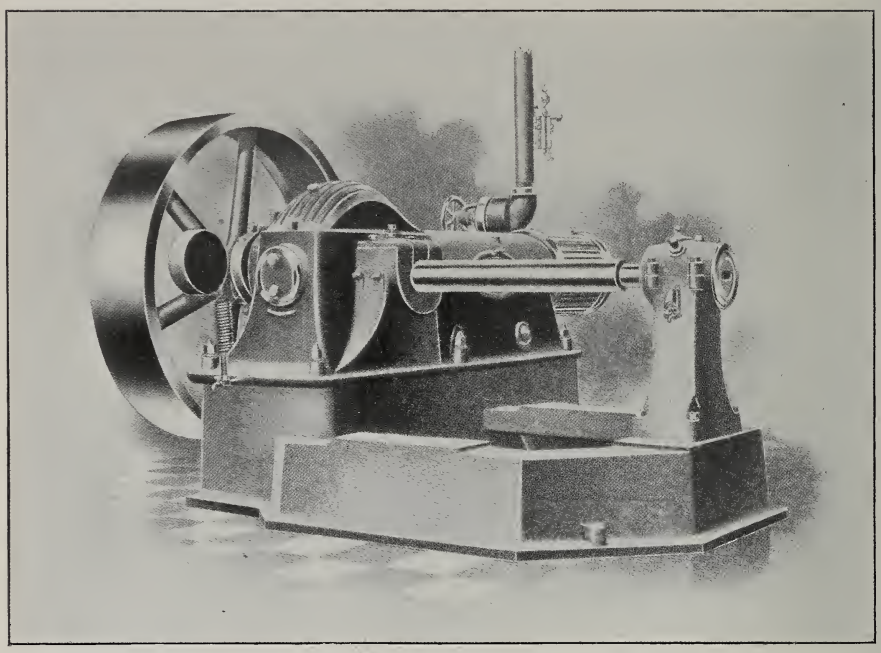


FIG. 7.—ENCLOSED SELF-OILING ENGINE BUILT BY THE BALL ENGINE CO., ERIE, PA.

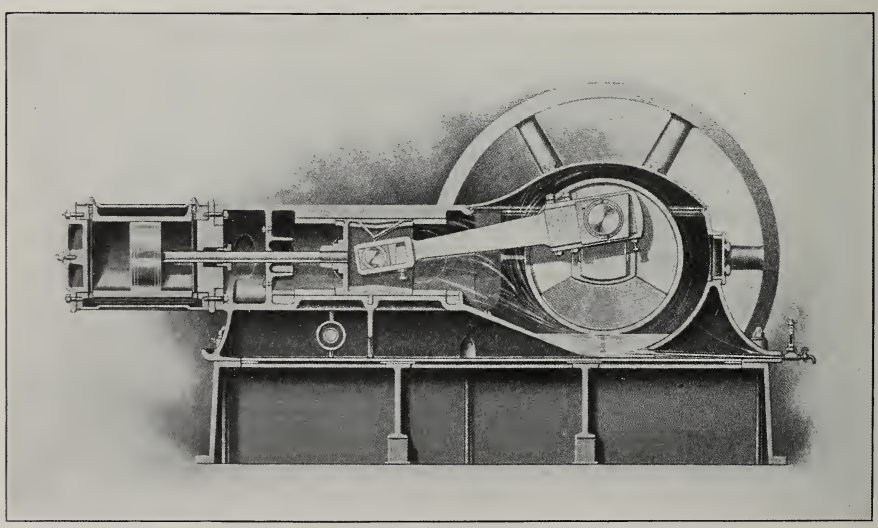


FIG. 8. -LONGITUDINAL SECTION OF THE BALL SELF-OILING ENGINE

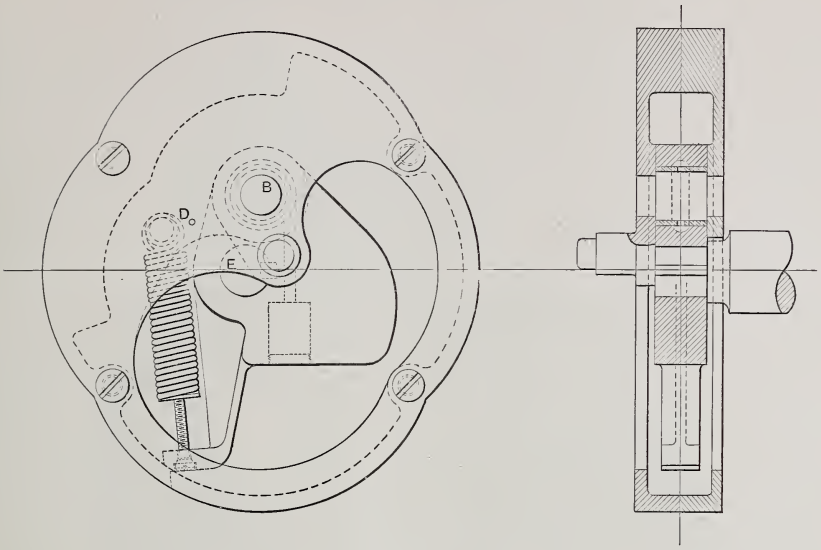


FIG. 9.—THE RITES GOVERNOR

gine, ranging from 10 to 125 horse-power, first introduced commercially by the Chandler & Taylor Company, of Indianapolis, Ind., has won popularity. Figs. 3 and 4 show engines of this type.

The single-valve automatic engine, ranging from 25 to 250 horse-power, has commanded much attention from designers, especially as applied to direct-connected electrical work. Figs. 5 and 6 show one built by the Harrisburg Foundry and Machine Works, Harrisburg, Pa., and Figs. 7 and 8, one built by the Ball Engine Company, of Erie, Pa. The system of automatic oiling shown in Fig 8 is much used, and was originally introduced by the late A. L. Ide, of Springfield, Ill. The principle is that the working parts of the engine are enclosed in a cast-iron case, in the bottom of which there is a bath of oil. The crank-disks and the connecting rod, as they revolve and reciprocate, splash the inside of the casing thoroughly with this oil, and as it drips down the sides it is carried off, in properly constructed channels, to those parts of the engine that need lubrication.

A marked advance has been made in perfecting the regulation of single-valve automatic steam-engines by combining, in the construction of the main shaft governor, the centrifugal force and the inertia of the governor weights. One of the simplest forms of this kind of governor is shown in Fig. 9, representing the designs of Mr. Francis M. Rites, of Ithaca, N. Y. This governor has

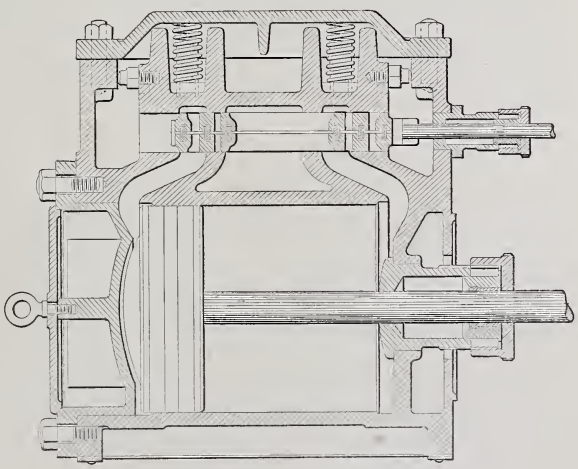


FIG. 10.—SECTION OF CYLINDER AND VALVE CHEST OF THE SHEPHERD ENGINE

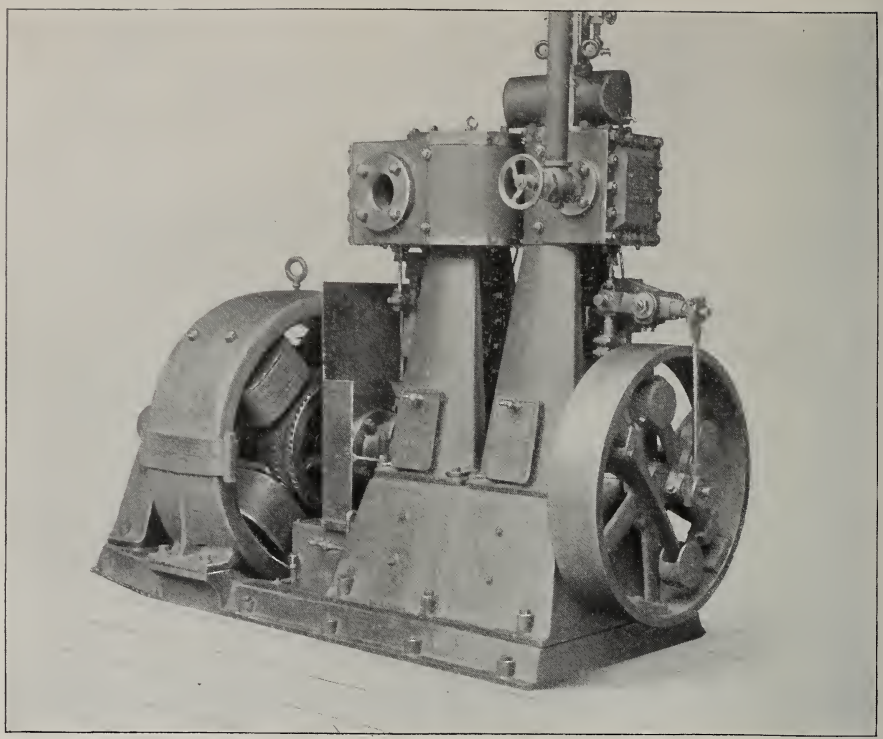


FIG. 11.—THE SHEPHERD VERTICAL ENGINE, BUILT BY THE AMERICAN FIRE ENGINE CO., SENECA FALLS, NEW YORK

but a single weight, with its centre of gravity very near the centre of the shaft, and supporting the eccentric, or pin, operating the valve-gear. As the load varies, the inertia of the governor weight almost instantly changes the position of the weight and adjusts the cut-off as required. The centrifugal force of the weight is resisted by a helical spring, and the relation between the centrifugal force and the tension of the spring determines the speed at which the engine is to run.

The American Fire Engine Company of Seneca Falls, New York, build a vertical engine for heavy work (see Fig. 11). It has a balanced slide-valve, shown in Fig. 10, which automatically takes up its own wear. The action of this valve is controlled by what is known as the Shepherd inertia governor.

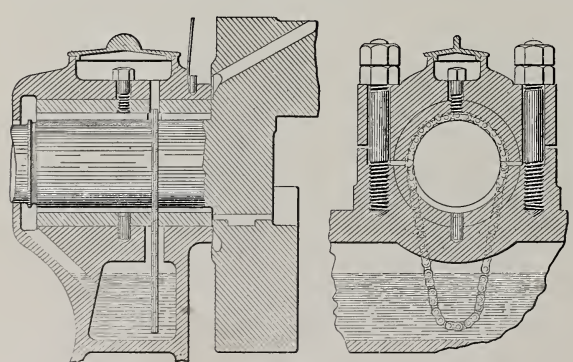


FIG. 12.—OILING DEVICE ON THE SHEPHERD ENGINE

The Ball Engine Company, of Erie, Pa., build a vertical engine of somewhat different design. The bedplate and frames are so constructed that the main shaft may be easily removed without taking apart the entire machine, as illustrated in

Fig. 13. Some builders of compound, single-valve, automatic engines prefer to have the governor control the valve of the high-pressure cylinder only; others feel that a better result is obtained when the governor controls the valves of both the high and low-pressure cylinder. The Ball Engine Company have adopted the first system and construct both tandem and cross-compound engines. The vertical engine shown in Fig. 14 is of this type. Those who adopt the second system are compelled to confine themselves to the tandem if they desire to secure the simpler construction of two valves connected by one valve-stem, which is so easily controlled by the governor.

A new horizontal compound engine has recently been brought out by the American Engine Company, of Bound Brook, N. J., in which one cylinder is placed immediately above the other, the two piston-rods connecting with one and the same cross-head, and one valve distributing the steam to both cylinders. One of these engines is shown in Fig. 15.

Of the double-valve engines, that made by the Buckeye Engine Company, of Salem, Ohio, is one of the most familiar. Their simple factory engine is shown in Fig. 16, while Fig. 17 represents one of their simple direct-connected generating sets. Fig. 18 is a direct-connected, tandem, compound engine of 250 horse-power. Within a few years this company has made a change in the valve used in their engines, and piston-valves, as shown in

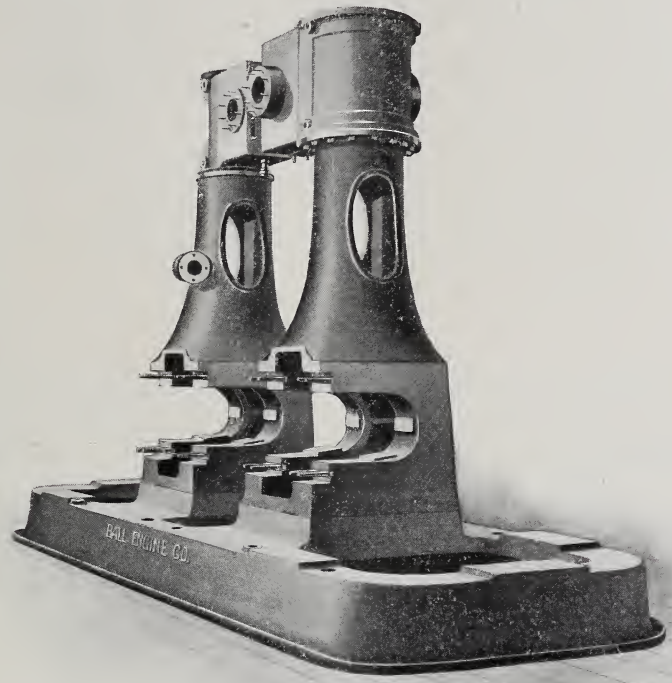


FIG. 13.—BED-PLATE AND FRAME OF BALL ENGINE, ILLUSTRATING METHOD OF REMOVING THE MAIN SHAFT

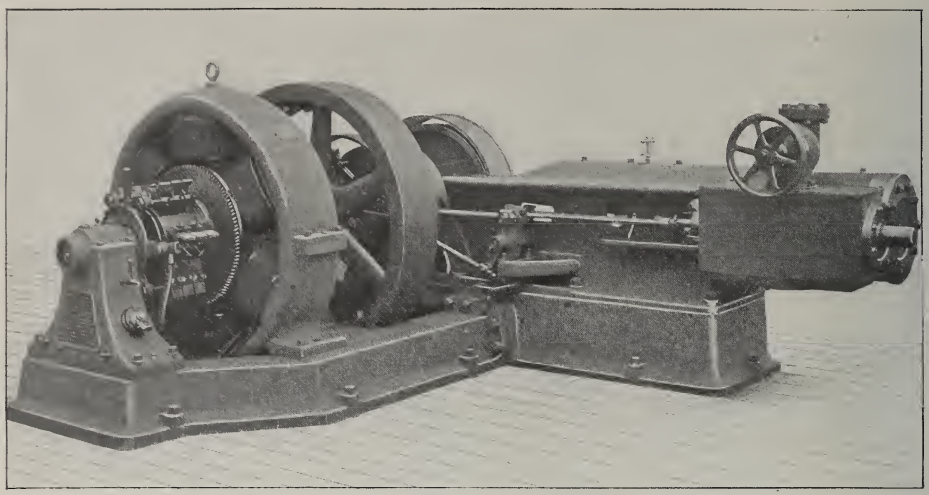


FIG. 17.—A BUCKEYE DIRECT-CONNECTED ENGINE

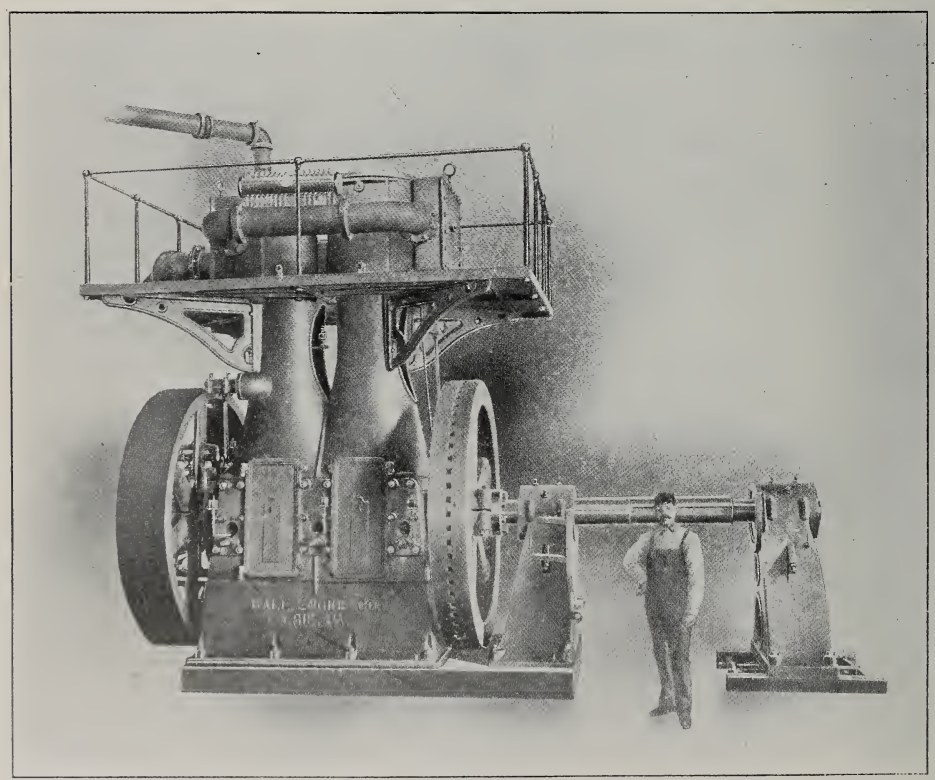


FIG. 14.—VERTICAL CROSS-COMPOUND ENGINE ARRANGED FOR DIRECT CONNECTION. BUILT BY THE BALL ENGINE CO., ERIF, PA.

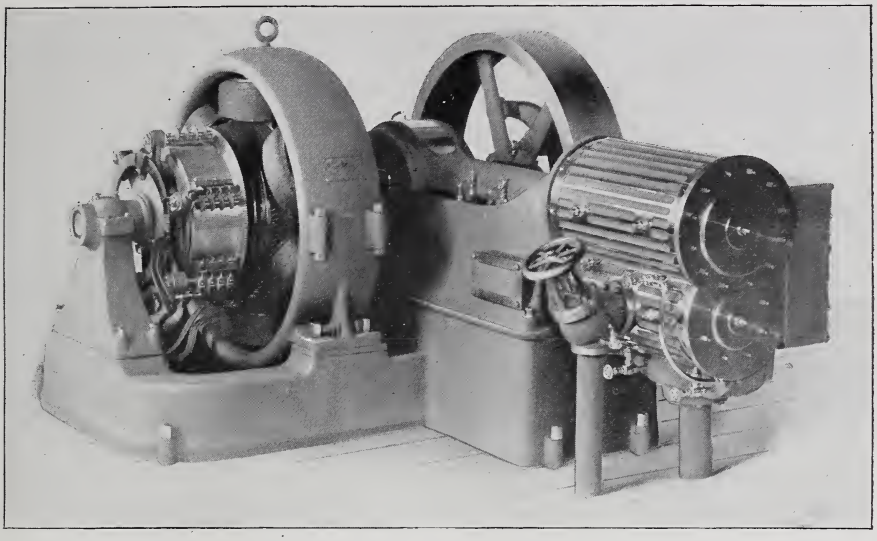


FIG. 15.—DUPLEX COMPOUND DIRECT-CONNECTED ENGINE BUILT BY THE AMERICAN ENGINE CO. BOUND BROOK, NEW JERSEY

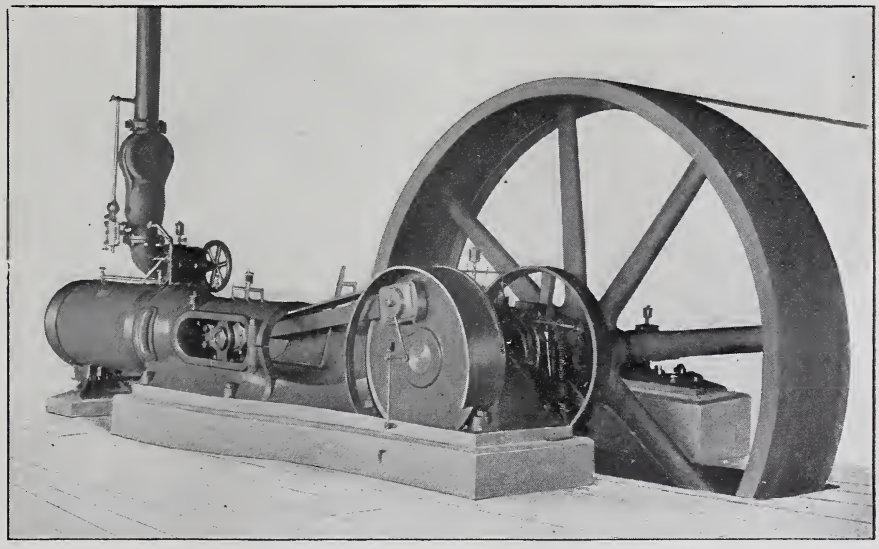


FIG. 16.—SIMPLE FACTORY ENGINE BUILT BY THE BUCKEYE ENGINE CO., SALEM, OHIO

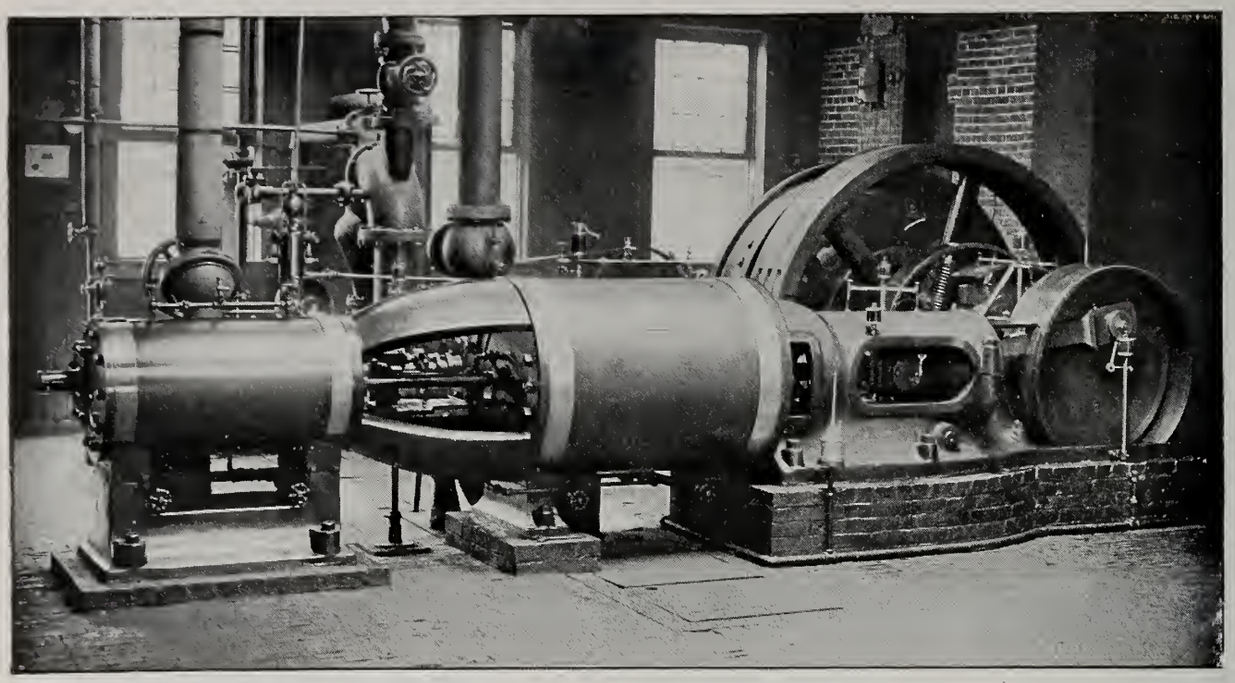


FIG. 18.—DIRECT-CONNECTED 250 H. P. TANDEM COMPOUND ENGINE. BUILT BY THE BUCKEYE ENGINE CO., SALEM, OHIO

Fig. 19, have replaced their former well-known box slide valves, retaining, at the same time, their celebrated valve motion.

When we consider four-valve engines, those fitted with the Corliss valve-motion easily lead in point of numbers, but there are others of this class in the market which are doing excellent service. give but little resistance, and are consequently easily controlled by a main shaft governor. The Corliss engines, made by the E. P. Allis Company, of Milwaukee, Wis., have a world-wide reputation. Within ten years they have designed a new form of bed-plate for horizontal engines which has been used largely by builders in Europe and

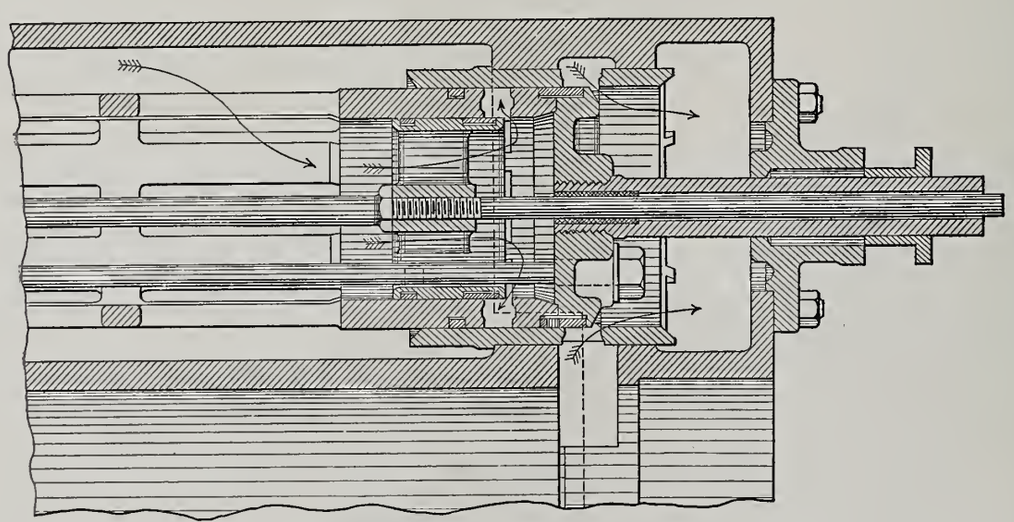


FIG. 19—THE NEW BUCKEYE ENGINE VALVE

Messrs. McIntosh, Seymour & Co., of Auburn, N. Y., have built some (see Fig. 20), remarkable for power, speed, and economy, with gridiron valves, which, as they have a very short travel, America. It is especially well adapted for engines of great power. This bed-plate consists of two parts, the larger embracing the main pillow-block and a hood terminating at the guides. The

smaller is a trunk, bored out for the guides, and connects the hood with the cylinder. (See Figs 22 and 23)

The Corliss valve-gear necessarily limits the speed of an engine, but this limit is gradually increasing, and some engines thus equipped are speeded at 150 revolutions per minute, whereas 100 revolutions per minute is sufficiently high. Under modern conditions it is often necessary for engines to carry heavy overloads, and a Corliss valve-gear with a single eccentric is not well adapted for this purpose. Therefore, double eccentrics are usually substituted, and they have this advantage over the single-eccentric gear, that more compression can be obtained and the engine can be made to run more quietly at high speeds. The Lane & Bodley Company, of Cincinnati, Ohio, make engines of this kind, and by omitting the wrist-plate, as shown in Fig. 24, they have simplified the valve motion.

The C. & G. Cooper Company, of Mt. Vernon, Ohio, manufacture large cross-compound engines, and an illustration is given in Fig. 21 of one direct-connected to a generator. It has two governors; one controls the valve motion, as usual, and the other, speeded slightly higher, controls a stop-valve in the main steam pipe. In case the first governor fails to control the speed, the second shuts off the steam supply and prevents the engine from running away.

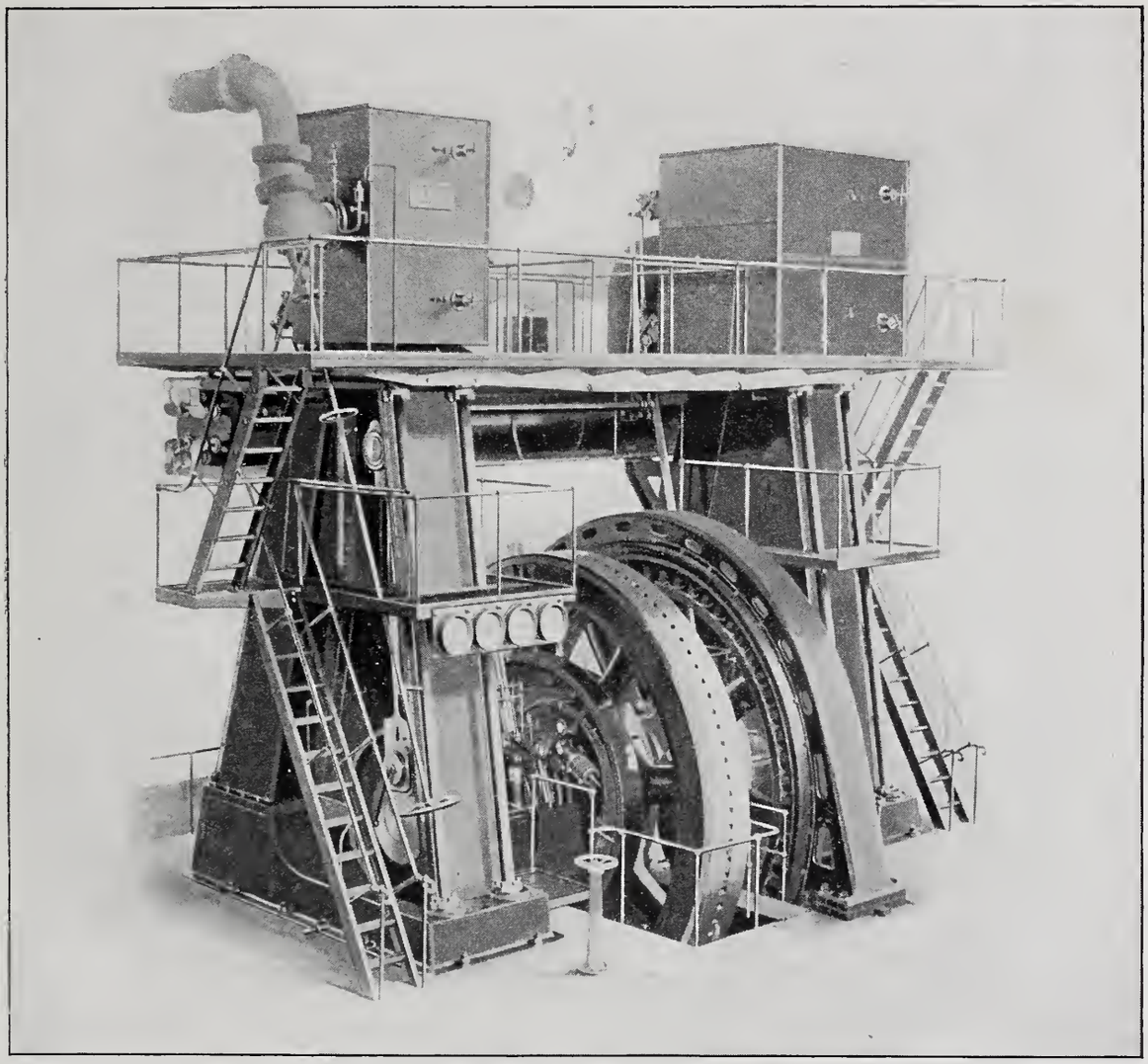


FIG. 20 —VERTICAL CROSS-COMPOUND ENGINE DIRECT-COUPLED TO A 1500 K. W. ALTERNATOR. CYLINDERS 28" AND 58" × 48". BUILT BY MESSRS. M'INTOSH, SEYMOUR & CO., AUBURN, NEW YORK

Mr. George I. Rockwood, of Worcester, Mass., has designed a number of compound engines, which nearly rival in economy their triple-expansion com-

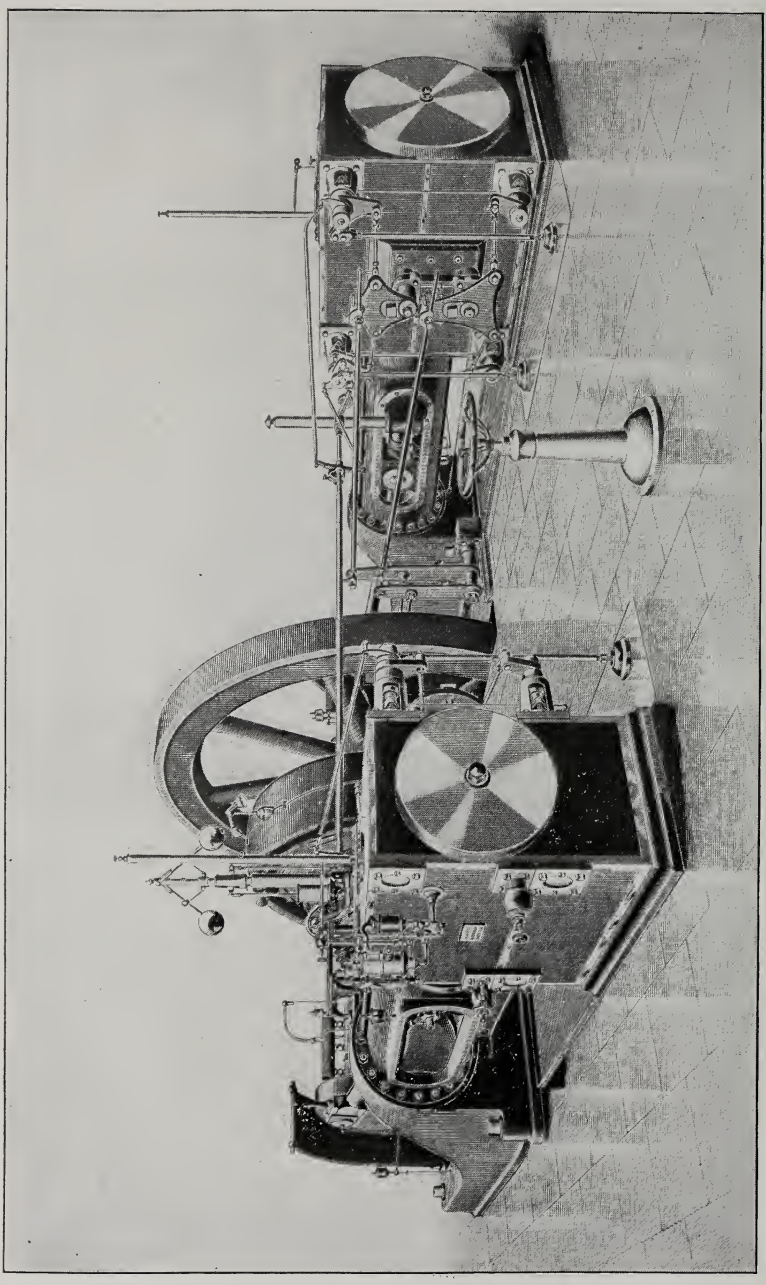
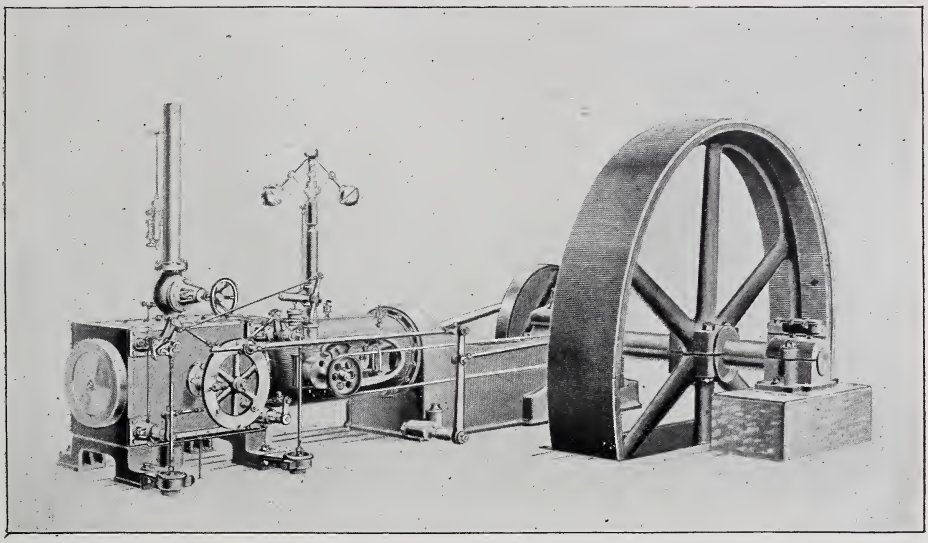
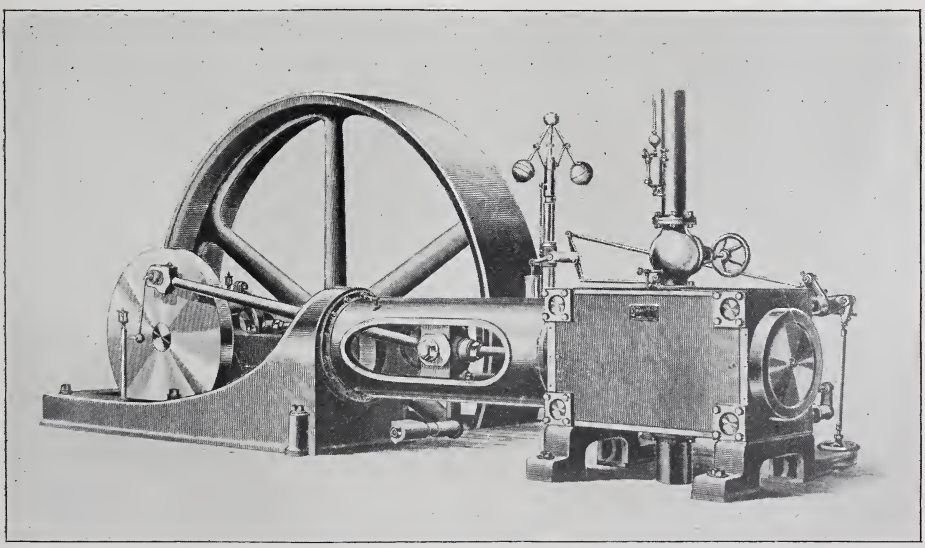


FIG. 21.—CROSS-COMPOUND, DIRECT-COUPLED ENGINE BUILT BY THE C. & G. COOPER COMPANY, MT. VERNON, OHIO





FIGS. 22 AND 23.—REYNOLDS–CORLISS ENGINE. BUILT BY THE EDWARD P. ALLIS CO., MILWAUKEE, WIS.

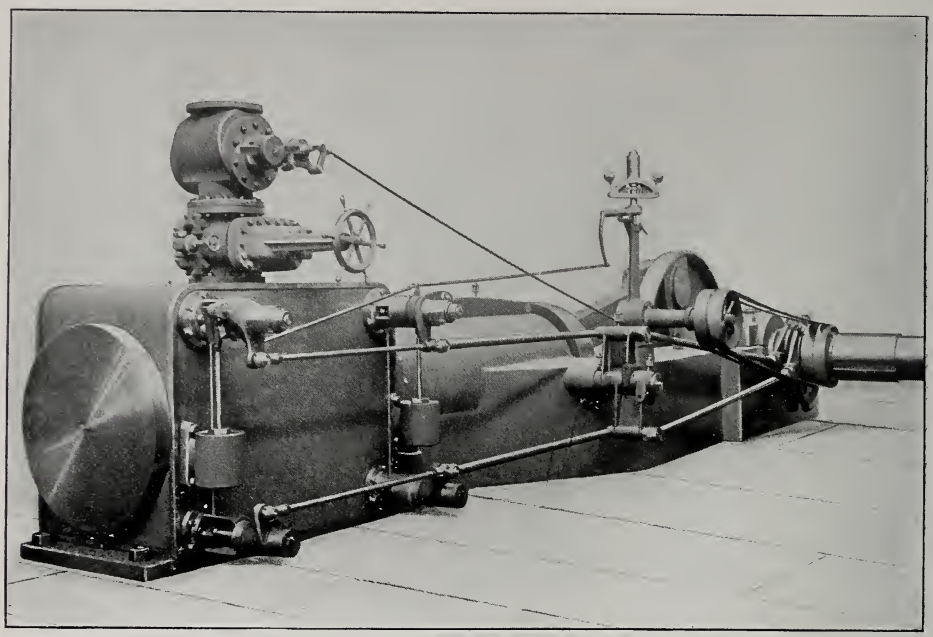


FIG. 24.—ROLLING MILL ENGINE WITH DOUBLE ECCENTRIC VALVE GEAR, DOING AWAY WITH THE NECESSITY FOR A WRIST PLATE. BUILT BY THE LANE & BODLEY CO., CINCINNATI, OHIO

petitors. They operate with about 25 to 35 expansions, and are thoroughly jacketed; they have a large receiver which is fitted with a re-heater of liberal capacity. With steam pressure of 160 to 180 pounds, and a ratio of the high to the low-pressure cylinder of about 1 to 7, he has secured from them an indicated horse-power with about twelve pounds of dry steam per hour.

Probably the most economical engine ever built is the pumping engine at a station of the Pennsylvania Water Company, near Pittsburgh, Pa., designed and constructed by the Nordberg Manufacturing Company, of Milwaukee, Wis. It has developed, with 1,000,000 British thermal units, very nearly 162,000,000 foot-pounds,—a most remarkable performance. It is a vertical, quadruple expansion engine, thoroughly steam-jacketed, made with the usual receiver and re-heaters between the cylinders. The peculiar feature of this machine is the series of feed-water heaters, which successively receive steam from the receivers, and the result is that the feed-water is pumped into the boilers at a temperature of 311 Fahr. The cycle here used resembles very closely the theoretical Carnot cycle, which is the most efficient cycle for the steam-engine.

From this brief review of different engine types it is easy to see that American, as well as other builders, can furnish engines for any and every service and of most excellent economy ratings.

SOME GEARING FOR ELECTRIC MOTORS

By Alfred H. Gibbings, M. Inst. E. E.

IT is not so many years ago when the electric motor was looked upon as an expensive and unreliable machine, in which the possibilities of breaks-down were as numerous as its many parts, and hence it was regarded with considerable suspicion and misgiving. Such an opinion was undoubtedly justified, for ample testimony to the difficulties, annoyances, and stoppages of work, frequent in their occurrence, can be given by those pioneers who had the confidence and the money to give this modern means of power transmission a trial. Here and there one comes across an occasional instance in which the electric motor turned out all it was supposed to be, due most probably to good design and good workmanship, coupled with other conditions of operation which happened to be favourable. In those days,—less than ten years ago,—motors were sometimes made by inexperienced firms who copied and adopted one form of design as far as exterior appearances went, but who calculated by rule of thumb the details of construction, with very little regard to the particular purpose for which the motors were required.

The one essential and predominating characteristic of the electric motor is its almost illimitable flexibility of design, by which it can be adapted to any class of machinery with equal satisfaction and little sacrifice of efficiency. This cannot be said of any other form of transmitting motion, and when taken in conjunction with the electric generator, which has very similar characteristics, the combination proves the most desirable and economical medium of transmitting and distributing electrical energy. At the present time the electric motor, in its semi-enclosed or enclosed form, has been brought to great perfection, and in those cases in which it has been installed under the specification or supervision of experienced electrical engineers it has proved entirely satisfactory and reliable.

A great deal has been written respecting the application of electric motors to driving machinery, each treatise usually dealing with some specific phase of the subject. Although it would be difficult to find any form of driving more suitable, more easy of operation, more adaptable, or so economical as the electric motor, yet the problem of securing all these advantages in combination at one and the same time involves much consideration and ingenuity. The very flexibility of the machine, by which it may readily be applied to almost any given set of conditions, renders its method of application,—except in the simplest cases,—a matter in which it is absolutely essential that experience should be brought to bear. What, for instance, does the manufacturer, mill owner, or any other power user know of the various methods of speed regulation of electric motors and the particular form which should be used to obtain the best result with the highest efficiency? Without taking into consideration special sets of conditions which are always to be met with in every factory in which many machines are employed, such general questions as the following must arise:—

1. Shall the motor be compound, series, or shunt-wound?
2. Shall speed regulation be effected through resistance in the armature circuit, or by means of specially winding the field coils, and, this being decided, then what type of resistance is best?
3. What temperature rise in the motor is permissible in any given case?
4. What motor speed will be con-

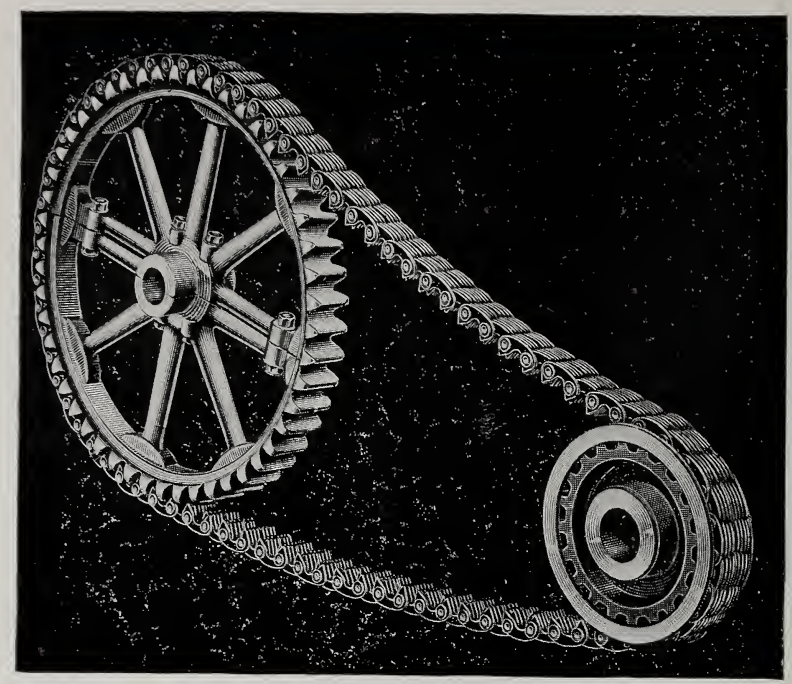


FIG. 1 —HIGH SPEED DRIVING CHAIN, MADE BY HANS RENOLD, MANCHESTER, ENGLAND

sistent with method of gearing to machine or shaft to be driven, and in the case of alternating current motors, what voltage, periodicity, and number of phases?

5. Will it be more economical, from a capital and works cost point of view,

FIG. 2.—ANOTHER VIEW

to drive each machine by a separate motor, or to group several machines through shafting to be driven by one motor?

6. Should motors be direct-coupled to a machine, or should gearing be employed?

7. What arrangements should be made in the case of certain machinery in which rapid reversals occur in the direction of driving?

FIG. 3.—FLAT BLOCK CHAIN

8. How far is it possible to carry the standardisation of motors, in order to avoid delay through accident, to effect repairs readily, and to reduce to a minimum the stock of spare parts which it is always necessary to hold in reserve?

In addition to these items there is always the question as to the reliability of any particular type of motor as regards its construction mechanically, which, unfortunately, no electrical test discloses. Want of

attention to, and knowledge of, some of the foregoing details has undoubtedly been the primary cause of the dissatisfaction which has occurred in some cases. It is no uncommon thing at all for the motor manufacturer to blame the user or his employee for want of care in handling the motors, while in reality the fault may arise from an entirely different cause.

The writer has assumed up to this point that it is well known and admitted that electrical driving carries with it considerable economical, as well as other advantages. If, however, in factories it is desired to work out and demonstrate this conclusion, the first points which are to be settled are (1) the difference in capital expenditure between driving electrically and driving by shafting: (2) the total horse power-hours per annum in each case, respectively; and (3) the saving anticipated.

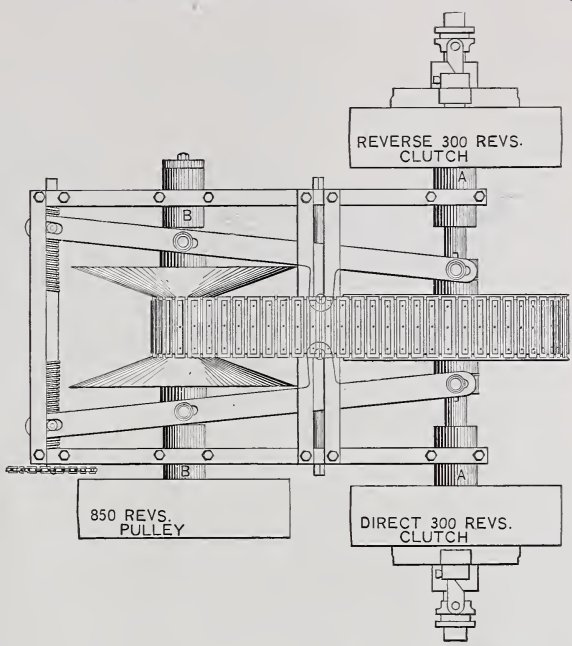


FIG. 4.—VARIABLE SPEED GEAR MADE BY THE REEVES PULLEY CO., COLUMBUS, IND., U. S. A.

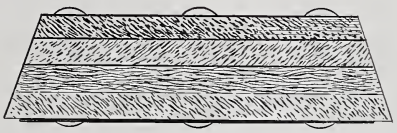


FIG. 6.—A CROSS SECTION OF THE BELT

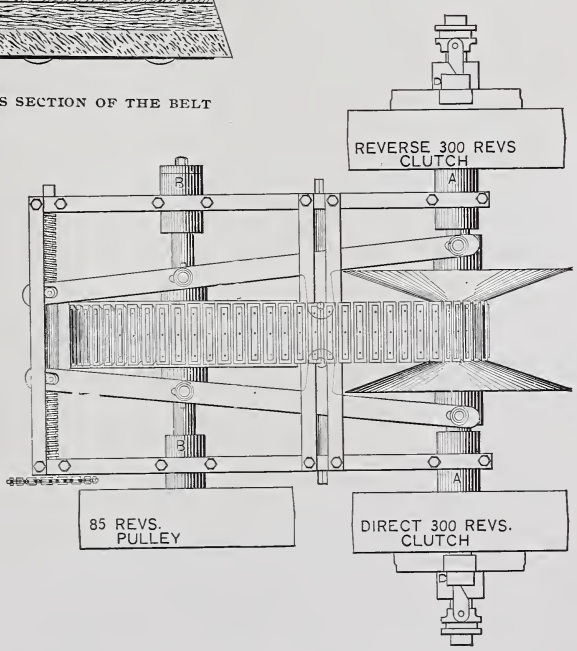


FIG. 5.—ANOTHER VIEW, SHOWING DRIVING AND DRIVEN DISCS IN REVERSE POSITIONS

It is clear that in order to arrive at the final result, the question of capital outlay plays an important part. With electrical driving the capital cost is, in most cases, much greater than, sometimes double, that for mechanical transmission, and there exists, therefore, the greatest necessity to avoid undue expenditure. It is apparent that such items as have already been enumerated here will have an important bearing upon this point, for economy in cap-

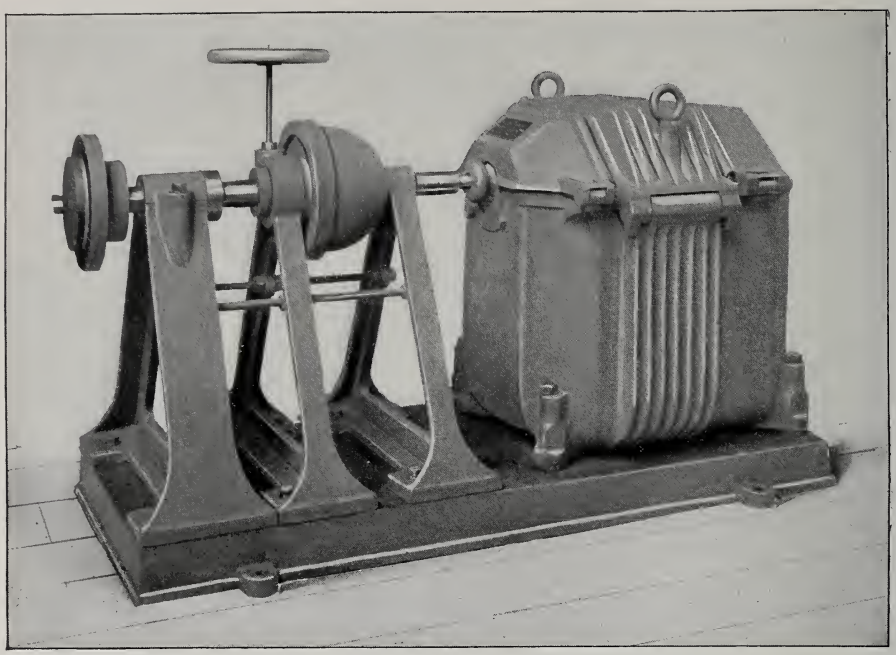


FIG. 7.—THE HUMPAGE GEAR, MADE BY THE EPICYCLIC MFG. CO., LTD., BRISTOL, ENGLAND

ital outlay will not only reduce the figure for interest and depreciation, but will most probably result in reduced running costs also.

It would be impossible within the narrow confines of an article to deal *in extenso* with most of the questions involved in deciding the correct form and method of electrically driving any piece or group of machinery. It needs but little technical knowledge, however, to see that it is absolutely necessary that each case should be considered and dealt with separately on its own merits, and that if there ever existed a more entire and conspicuous exception than any other to which the rule of thumb was quite inapplicable, it is the electrical equipment for the transmission of power in factories.

By reference to the list setting out the points bearing upon this matter it will be seen that, in their nature and substance, they are about equally divided between the mechanical and electrical, and further, that the one aspect very largely affects the other. Reference has also been made to the fact that some simple cases exist in which the motor can be applied to a machine, but in which it would be expensive to make the speed of the motor conform to the speed of the machine for direct coupling or in which variations in speed are required. The question is then resolved into the form of gearing most effective for the purpose. I propose, therefore, to give a few examples of some modern forms of gearing and to divide them under the following heads:—

1. Short drives.
2. Variable speed gear.
3. Definite reductions with a wide difference in speed.
4. Definite reductions in which the speed ratio does not exceed 10: 1.

1.—*Short Drives.*—In those cases in which short drives are compulsory the conditions may be of the very widest divergence. It is not proposed, therefore, to deal descriptively with all the common or well-known methods of gearing which it is possible to utilise; but the principal may be enumerated as follows:—Open and crossed belts; belts in combination with jockey pulleys;

spur gearing; worm gearing; friction gearing; chain gears. In adopting either one or another of the foregoing methods there are two factors which have to be taken into consideration,—the nature of the work to be performed, and efficiency. As a matter of fact, until the electric motor made its début as the means of transmitting energy, the enormous power wasted by some forms of gear was little dreamt of, and the question of efficiency was not considered. As long as the gear possessed a good factor of safety and was sufficiently convenient for the purpose the necessary coal bill was accepted without scrutiny and as a matter of course. At the present day, however, while we cannot, of course, afford to neglect either safety or convenience of gearing, the highest possible efficiency is also a *sine qua non.* Hence we see rapidly disappearing the short, tight belt-drive, with its inevitable slip and high friction loss. Crossed belts and jockey pulley arrangements are out of the running as regards modern efficiency requirements, and friction gearing is used only in exceptional cases. Worm gearing is advantageously employed in such cases as driving three-throw pumps and travelling cranes, and in similar cases in which great speed reductions are necessary. It has, however, the disadvantages of low efficiency (about 60 per cent.), even with the best construction and with the worm running in an oil bath, and involves the undesirable necessity of using a thrust bearing.

The most reliable and efficient gears for short drives are undoubtedly spur and chain gears. Well made machine-cut spur gear, in which the proportions of the wheels are not extreme, and assuming always that a single reduction is sufficient, is a very good form of short drive. It is not advisable to use it, however, unless some reduction or increase in speed is also required, and then one of the wheels should be morticed with hornbeam teeth or a rawhide pinion should be employed. Chain gear is rapidly superseding all other forms of gearing for short drives, both for reductions and increases of speed, and it possesses most of the characteristics of spur gearing, with, however, some additional advantages. It is, in fact, a better method of connecting spur wheels without direct engagement, and this allows of better proportions of wheels being designed. Figs. 1, 2 and 3 show illustrations of two forms of chain gearing which are designed, respectively, for high speeds and power, and for low speeds. These chain gears are made by Mr. Hans Renold, of Manchester, England, who has given special attention to the subject.

2. *Variable Speed Gear.*—In some cases it is desirable to use a gear in which niceties of adjustment in speed can be effected without stopping the machine and which is operative in each direction of rotation. It is obvious that to accomplish this, some loss of efficiency must inevitably occur even with the best apparatus, but with a badly designed gear or arrangement of gearing the loss may be a very serious matter. It is, of course, quite possible that the regulation of speed within the limit required may be economically effected by means of the motor itself, and, therefore, it is most essential to know what percentage of the power transmitted is actually used, whichever method may be adopted. For instance, the cut on a lathe, especially on face work, sometimes changes in diameter with every revolution, and hence the speed of rota-

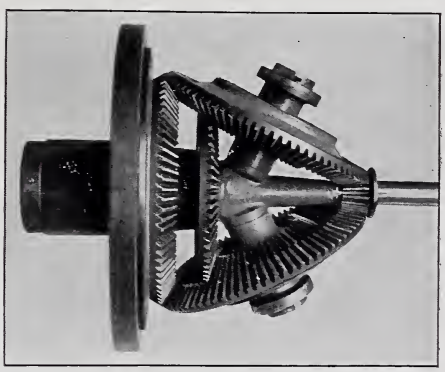


FIG. 8.—SECTIONAL VIEW OF THE HUMPAGE GEAR

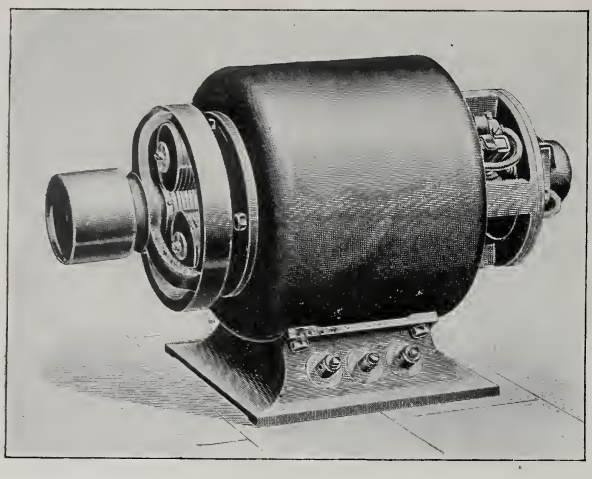


FIG. 9.—THE TWENTIETH CENTURY SPEED REDUCER, MADE BY MESSRS. BROWN & CO., MANCHESTER, ENGLAND

tion should be such as will always ensure the same cutting speed. With regard to almost every tool in a machine shop, the same possibilities of adjustment are desirable, and so it is evident that a gear for this purpose is very necessary. Such a gear is illustrated in Figs. 4 and 5, and this particular type is made by the Reeves Pulley Company, of Columbus, Indiana, U. S. A. The distinctive features of this gear, it will be seen, are two sets of cone discs mounted on two parallel shafts. One disc of each set is attached to a common pivoted straight bar, which bar is operated upon by a screw in such a manner as to bring together one set of discs as the other is forced apart. The inner sides of these discs form a V-shaped groove in which is fitted a specially designed belt, having its bearing upon the edges instead of the bottom as in an ordinary belt. The operation is very simple. One set of discs acts as driver, the other as driven. As the driving circumference of one is increased, the other is decreased. The variation in speed is, therefore, anything within the compass of the two extremes. It is also possible to use either set of discs as the driver.

This gear has not yet been very extensively adopted in Great Britain, partly because its cost is high, and partly because the uses and purposes to which it can be applied economically are not great. Where variable speeds are required while the work is in progress and in which the limit of variableness is such as this gear is designed to provide, the whole question is resolved into the two factors of practicability and efficiency, as compared with regulating the motor speed. Each can be operated by automatic mechanism.

3. *Definite Reductions with a Wide*

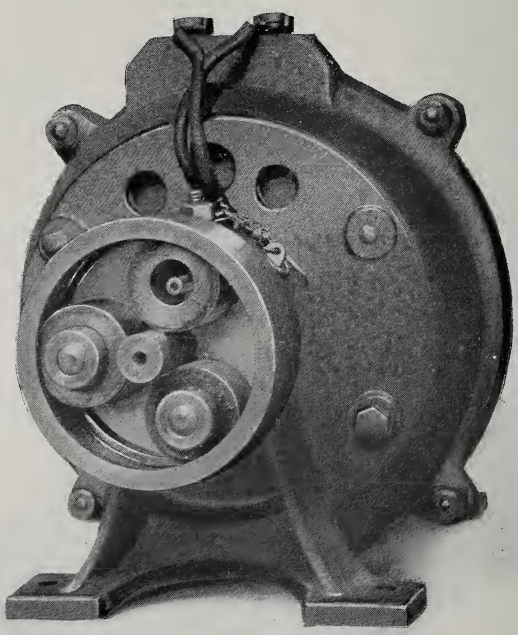


FIG. 10.—ANOTHER VIEW

Difference in Speed.—A very slow rate of revolution is sometimes required with different engineering tools, such as in boring out large steam engine cylinders and in lathe work in which large diameters occur. Other special cases will, no doubt, occur to the reader's mind in which the difference in speed between that of an ordinary line shaft (say, 120 revolutions per minute) and the tool (say, 1 to 5 revolutions per minute) is so wide as to necessitate the use of several reductions of spur wheel gear or much countershafting. When the driving power is obtained from an electric motor running at 600 or 800 revolutions per minute, the conditions are not improved. A gear to meet this requirement, and which occupies only a small space, is now being made by the Epicyclic Manufacturing Company, Ltd , of Bristol, England. This gear, known as the Humpage gear, is an epicyclic gear, and the principle is eminently adapted to wide differences of speed between driver and driven. The apparatus or mechanism is simple, and has been described technically in other journals, but these details are outside the scope of the present subject. Notwithstanding the simplicity of the arrangement itself, very little is yet known of the actual strains, stresses and wear of the gear wheels in their relation to each other in this apparatus and hence the manufacturers are making exhaustive tests and are standardising their various sizes. The object to be attained with this and all other gears (after the ratios have been determined) is that of the highest efficiency, at the same time allowing a proper margin of safety. But the whole question is indeed an extremely abstruse one, involving an immense amount of calculation over a field well known, but never apparently properly investigated. An illustration of the Humpage gear is given in Fig. 7, in which the electric motor shaft is coupled direct to the gear shaft. The other end of the gear is the slow speed side for coupling to the work either directly, as shown, or by means of a belt. Another view of the gear is given in Fig. 8.

The standard sizes in which this gear is made are as follows :—On the quick speed side,—

1, 2, 3, 4, 5 and 6 H. P	1600	revs. per minute.
10, 15, 20 H. P	1200	" "
25, 30, 35, 40 H. P	1000	" "
45, 50, 60 H. P	800	" "
70, 80, 90, 100 H. P	600	" "

On the slow speed side,—

1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90 and 100 revs per minute.

4. *Definite Reductions in Which the Speed Ratio Does not Exceed 10:1.*—The Humpage gear just mentioned can be designed to give any reduction in speed which may be desired, but the makers apparently do not anticipate its chief application within the 10 to 1 ratio, but rather for wider differences. This is due principally to the difficulties in design already referred to in which the necessary factor of efficiency is somewhat problematical. Another gear, however, has recently been put on the market, in which, curiously enough, the ratio of reduction is better confined within the 10 to 1 limit. Illustrations of this are given in Figs. 9 and 10, the rim of the gear in the latter acting as the pulley, while in the former case a smaller pulley is attached to the gear rim. It is claimed for this speed reducer that the speed of an electric motor can be reduced in any desired ratio with ease and without complication, and that increase of speed can also be similarly obtained. The gear is called the "Twentieth Century Speed Reducer," and consists of two fixed rollers and one free roller operating together by friction upon an outer cast-iron rim, and upon the shaft of the electric motor. The difference between the circumference of the shaft and the circumference of the rollers gives the ratio of the reduction or the increase of speed as required. This is practically a friction gear. The drive, however, is positive, and slip is entirely impossible, not even if the entire gear works in a bath of oil. A test made to ascertain the friction or loss in the motor was found to be less with the speed reducing gear attached and doing the driving, than when the motor was arranged for driving in the ordinary manner.

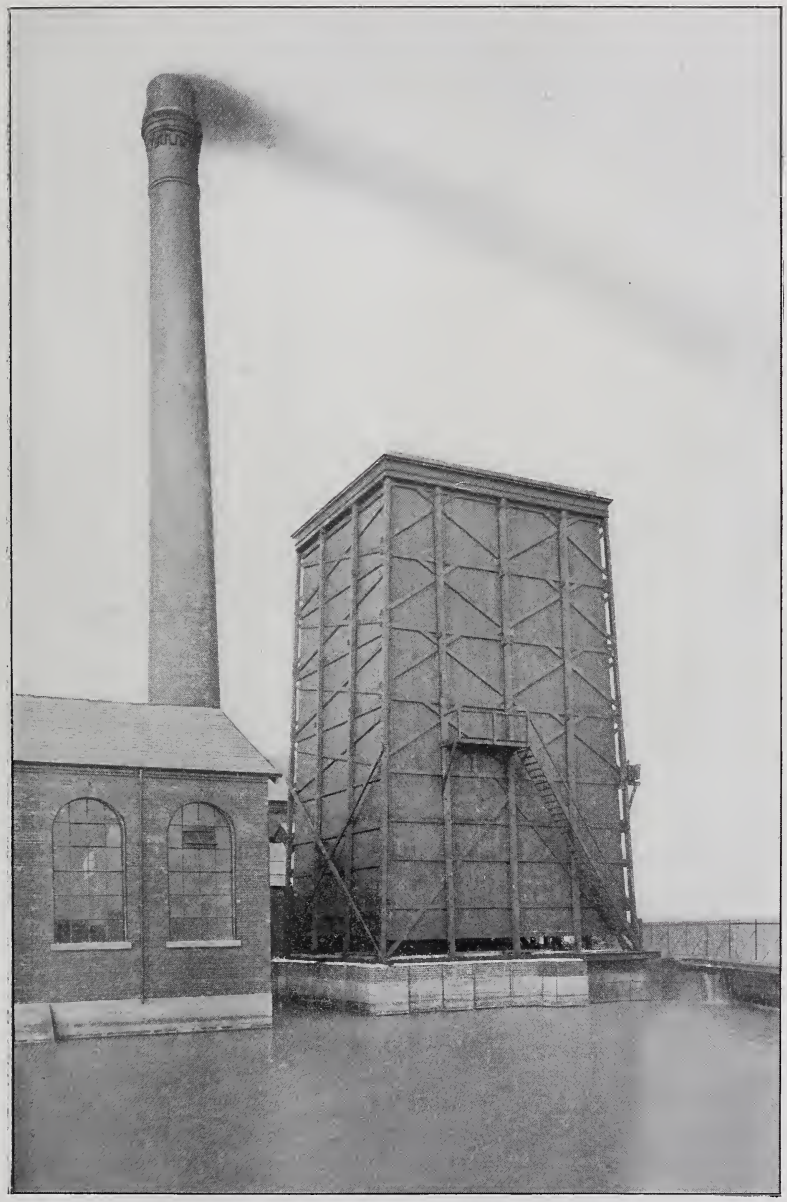
WATER COOLING TOWERS

By J. A. Reavell

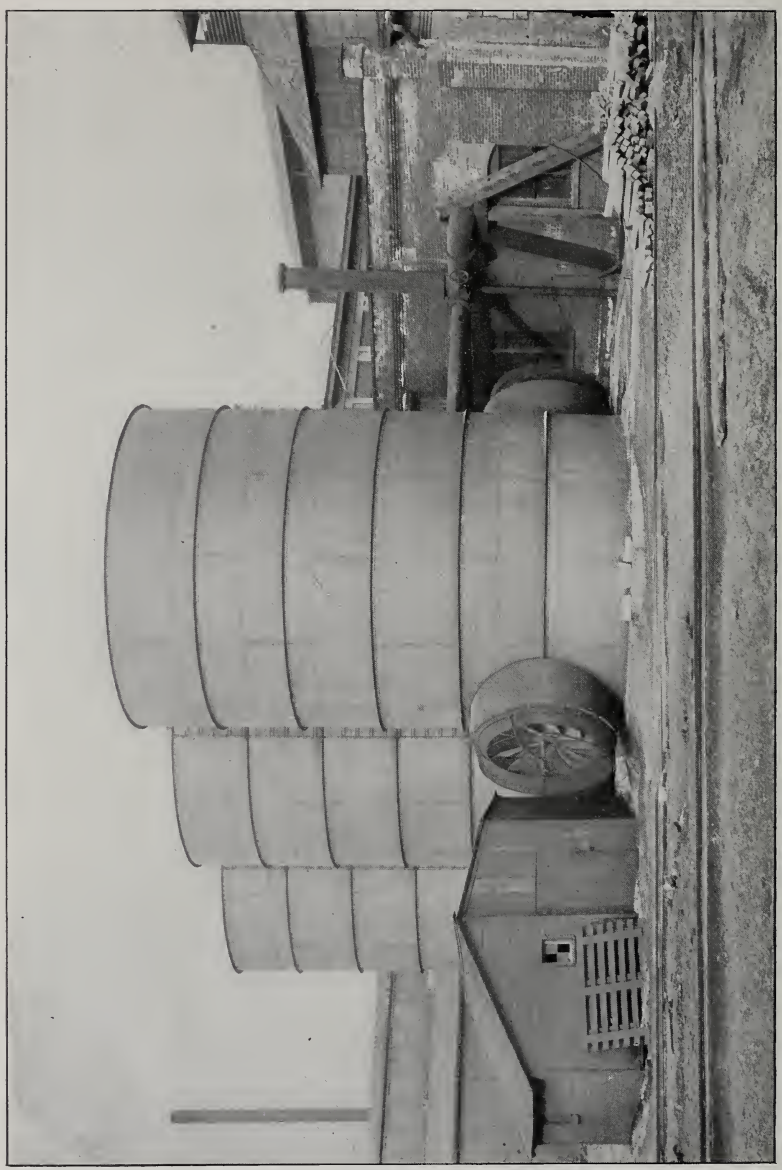
A 4000 H. P. BARNARD-WHEELER WATER COOLING TOWER OPERATING AT THE PLANT OF THE MISSOURI-EDISON ELECTRIC CO., ST. LOUIS, MO., U. S. A INSTALLED BY THE WHEELER CONDENSER AND ENGINEERING CO., NEW YORK AND LONDON

IN a modern steam plant having condensing engines, the question of deciding whether jet or surface condensers should be used must, in each case, depend entirely on the local conditions, and especially on the quality of the water available for condensing purposes. Where natural supplies of water for circulating purposes are not available, it has always been a problem for the engineer how to run his engine condensing, though several methods are now well known and in more or less extensive use,—first, by evaporative condensers; and second, by cooling the water after leaving the condensers and using this water over and over again.

There are several methods of cooling the circulating water to be used either with surface or jet condensers. Where a large area of land is available, which is of little or no value, a pond can be made and arranged so that the hot circulating water enters at one end and is withdrawn at the other by the circulating pump. Where such a pond is used, the cooling action depends entirely on radiation, and this is controlled by the state of the atmosphere, both with re-



A COOLING TOWER AT THE GENERATING STATION AT BISPHAM OF THE BLACKPOOL & FLEETWOOD TRAMROAD COMPANY. ERECTED BY THE KLEIN ENGINEERING CO., LTD., MANCHESTER, ENGLAND



A BATTERY OF THREE COOLING TOWERS AT THE WORKS OF THE CONSOLIDATED STEEL & WIRE COMPANY, CLEVELAND, O., HAVING A CAPACITY OF 5000 H. P., OR 100,000 POUNDS OF STEAM PER HOUR. JET CONDENSERS MAINTAIN VACUUM AND ELEVATE WATER TO COOLING TOWERS. INSTALLED BY H. R. WORTHINGTON, NEW YORK AND LONDON

gard to humidity and temperature. Then, again, in the construction of cooling ponds care must be taken so as to get the depth exactly right; if too deep, the cooling is not at all efficient, while if too shallow, the sun in the summer time prevents the water from cooling. The defects of the system are that a large area of land is required and the water can be cooled only under certain atmospheric conditions.

Another method is to reduce the size of the pond and to arrange a system of water pipes above the pond. These pipes have a series of jets or sprays placed at certain distances apart and pointing vertically upwards. The pipes are fed by a main running along one side of the pond. The idea of this form of cooler is that the water is sprayed from the jets and divided into small globules, which, in falling back into the pond, are cooled by contact with the atmosphere.

The space occupied when cooling a given amount of water in this way is much less than that required by a pond; but, on the other hand, there is more loss of water by vaporisation. Generally speaking, the spray arrangement is more expensive to build than the pond, and necessitates more work put on the circulating pump in order to force the circulating water through the nozzles to give the spraying action required.

A third method of cooling is by means of the wood pile. This is adopted to a large extent on the European continent. A pond or reservoir is constructed, in the centre of which a vertical pipe is erected, and around this is fixed a large stack of brushwood. The water, on discharging from the pipe, is distributed over the brushwood, and in trickling down is cooled, owing to its being divided up into small particles and exposed to the surrounding atmosphere. The drawback to this form of cooler is that the brushwood has to be frequently renewed, and also that, owing to the

WHEELER–BARNARD WATER COOLING TOWER AT THE BELFAST CORPORATION ELECTRICAL STATION. BUILT BY THE WHEELER CONDENSER & ENGINEERING CO., LONDON AND NEW YORK

space required, it cannot be used for large powers.

Still another form of cooler is a German invention, and is built by the Klein Engineering Company, Ltd., of Manchester, England. Of this there are two types, one arranged for natural draught, and the other for forced draught. They are built of wood. In these coolers the water is delivered to distribution troughs from which it descends over a series of wood splines, and the current of air, passing up through the tower, cools the water. The forced draught tower is practically the same in design, except that the air is delivered through a fan at the base of the tower and the top is carried up in the form of a chimney to help the draught. The arrangement of the splines is such that both they and the falling water offer a resistance to the air from the fans.

All of the above forms of cooling towers have to be erected upon the ground level and over some form of tank or pond, but the following types to be described have the advantage that they can be erected not only on the ground level, but also on the top of buildings, and for power stations in cities where ground area is of great value this is of importance. They are also built of steel, so that they have the advantage of lightness in weight, and also in their design they require much less base area when cooling a given quantity of water.

One form of such steel tower is built by the Henry R. Worthington Company, of New York and London. It is cylindrical in design, with a central pipe up which the hot water is forced. The top consists of a swivel head. Radiating from this are the water distribution pipes, each having a series of nozzles, and as the water is discharged through these it makes the swivel head, and consequently the radiating pipes connected to it, revolve so that the hot water is distributed.

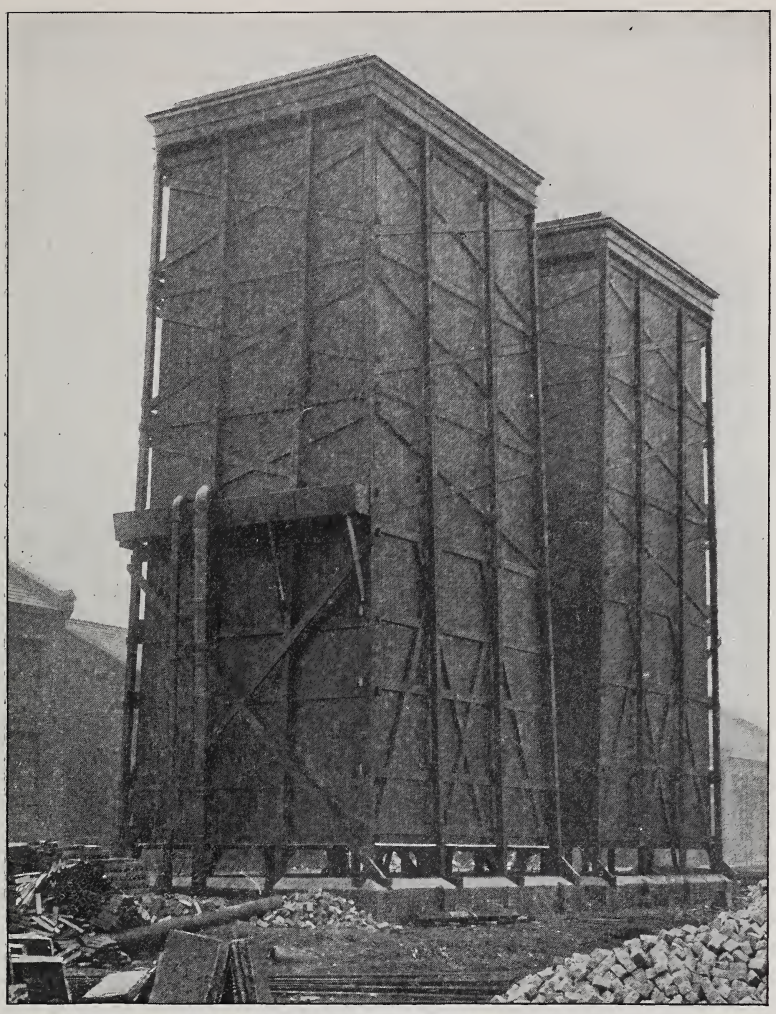
The tower, below the distributing pipes and down to within a certain distance of the base, contains a series of short pipes, arranged with the joints broken. The water, after delivery from the distributing pipes, is continuously being broken up as it trickles from one layer of pipes to that immediately below it.

At the base of the tower is a fan, and the air is forced up through the spaces between the pipes. This arrangement of pipes has the objection of offering resistance to the air in passing up through the tower, owing to the constant change in direction and in the friction from the water dropping from one set of tiles to the other. The tiles, or pipes, are sometimes made of clay, and sometimes, too, of iron. When this tower is run without fans, the current of air is obtained by running up the height of the tower in the form of a chimney. To give the best results when using natural draught, the height of the chimney is made equal to about the height of the water distribution part from the ground level.

Another tower, also of steel, is that made by the Wheeler Condenser and Engineering Company, of London and New York, known as the Barnard-Wheeler cooling tower. This is of rectangular construction when used for forced draught, but when natural draught is used the design is of the circular form. The great advantage of the rectangular form of tower is that it can be adapted to almost any available space and lends itself to easy means of extension. In the circular forms this cannot be well done.

Along each of the two long sides at the top of the tower are troughs into which the hot water is delivered. Running across from one trough to the other are pipes about 1½ inch in diameter, spaced about 3 inches apart. These pipes are perforated along the side, and from each is hung a steel galvanised wire mat, held by top hooks, and to cross-stays, which are fixed above the fan openings.

The fans deliver the air up through the mats, there being ample space between them, so that resistance to the air is reduced to a minimum. The water, being delivered into the troughs, passes along the tubes and through the perforations, impinges on the plate at



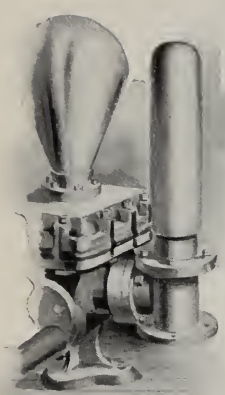
TWO CHIMNEY COOLERS ERECTED AT THE ST. HELEN'S CORPORATION ELECTRICITY WORKS BY THE KLEIN ENGINEERING CO., LTD., MANCHESTER, ENGLAND

the top of the mat, and then descends down the mats. The whole mat is thus completely covered with a thin sheet of water, on each side of which are the currents of air from the fans.

These towers can be, and are, erected on the tops of buildings or in any position, and are not restricted to erection on the ground level. When used with surface condensers, the height is no object, for, with the exception of pipe friction, it throws no more duty on the pumps than if the tower were on the ground level. The open type of cooler made by the Wheeler Company has a central column which forms the uptake for the hot water, and from the top of this radiate a set of pipes which feed into a radial trough having a set of perforated pipes radiating from it. From each of these perforated pipes is hung a wire mat, as in the enclosed tower. All these mats radiating from one centre are each exposed to the air currents, and the water is cooled as it descends.

SUCTION AIR CHAMBERS FOR PUMPS

By F. Meriam Wheeler, M. E.



A PROMINENT engineer directly interested in the installation of steam and electric-driven pumps, recently called upon the writer to discuss the best manner of installing such pumps, particular emphasis being given to the use of suction air chambers and the best location of these. We both agreed that in arranging the suction connections of a pump, especially where the supply pipe is quite long, it should be remembered that the moving column of water in this pipe will have considerable dynamic energy, and if any attempt be made to check its flow suddenly, water hammer must certainly be the result. To avoid the noise and serious effect of water hammer, a suction air chamber should be used, but it is most important that this chamber be properly located. The writer cited many cases where suction air chambers had been so placed that they were of little or no use, and one or two of such cases are referred to later in this article.

Experience proves that water or other liquids, passing under or across the opening of an air chamber placed at right angles to the flow, will cause the pump to pound about as much as if no air chamber were used,— except at a low rate of speed. Therefore, in arranging suction air chambers the writer always urges that they be so located that the energy or momentum of the column of water can be expended directly upon the confined air in them. In other words, we must get the proper cushion for the column of water while the piston of a pump reverses at each stroke when running at anything but slow speed.

The writer recently tested a small compound steam pump to demonstrate not only the advantage of the use of a suction air chamber, but also to show the respective merits of two arrangements of suction air chambers. As shown in Fig. 1, one arrangement was to have a suction air chamber on the opposite side of the pump to where the supply entered. The other arrangement was the location of the suction chamber in a direct vertical line with

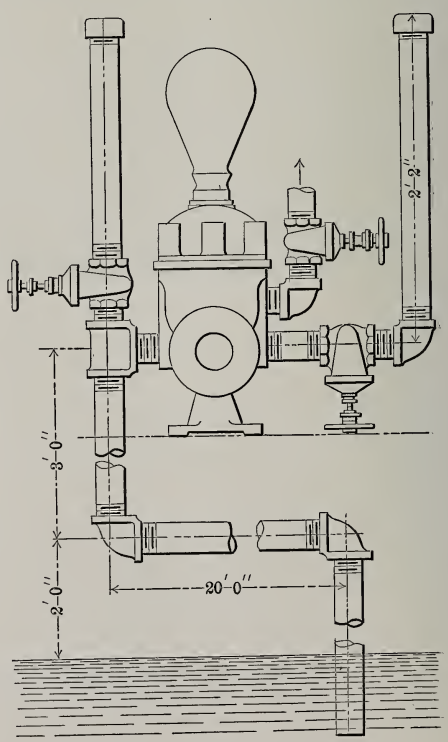
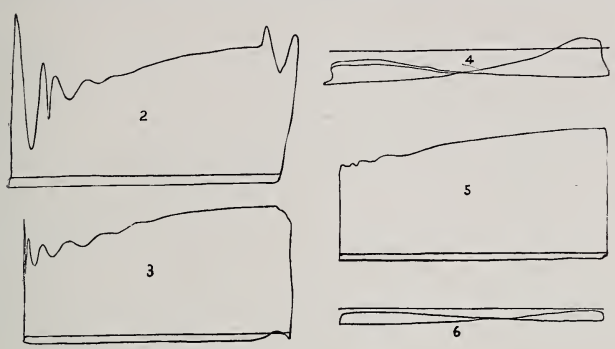


FIG. 1

the suction pipe, the latter being placed on a tee. Gate valves were provided so that either or both suction air chambers could be shut off and opened at will.



FIGS. 2 TO 6

At a slow speed, with both chambers out of use, the pump ran quietly, but when the number of strokes was increased to a fair rate of speed, water hammer was the result.

To give an idea what serious effect water hammer has on the piping as well as on pumps themselves, the writer would call attention to the fact that this pump (intentionally left unbolted to its foundation, while the piping was entirely free to move) at eighty double strokes per minute produced water hammer so badly as to cause the suction pipe to move back and forth at least one-half inch horizontally. When either suction chamber was opened there was no perceptible movement in the pipe, and the pump ran absolutely quiet. The pump drew its supply from a tank below, the total suction lift being about 5 feet, measuring from the centre of the suction inlet, while the length of horizontal suction pipe was about 20 feet.

The indicator cards submitted are quite an interesting study. All the cards were taken while the pump was running at eighty double strokes per minute, with a water pressure of seventy-five pounds per square inch, the pressure in the steam chest of the high pressure cylinder of pump being about sixty pounds. Fig. 2 shows the pump running with both suction chambers cut off. As stated above, the pump was then very noisy owing to water hammer. Fig. 3 shows an indicator card taken from the water cylinder of the pump with one suction air chamber in use,—the one located on the tee. Fig. 4 represents an indicator card from this suction air chamber.

The gate valve on the first-named suction air chamber was then closed and the valve on the other suction air chamber, placed on the elbow at the opposite side of the pump, was opened. Fig. 5 shows a card taken from the water cylinder with this elbow style of suction air chamber, while Fig. 6 shows a card taken from the suction air chamber itself. It will be seen from these cards that the suction air chamber located on the elbow was more efficient than the other (tee style) suction air chamber. The gate valves were wide open when

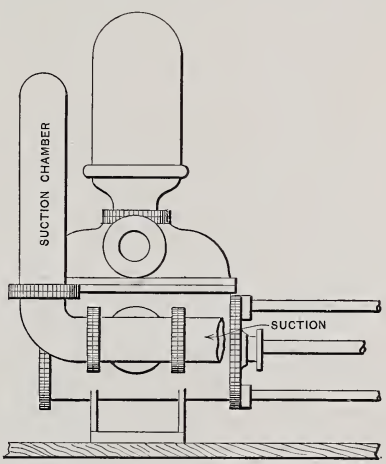


FIG. 7

the indicator cards were taken from the chambers, but it was noticed that when the gate valve on the elbow chamber was opened, it required only about one turn to stop the water hammer, while in the case of the suction chamber placed on the tee it required nearly two turns

of the valve to get the same effect. The suction pipe to the pump measured 2 inches,—hence had an area of 3.14

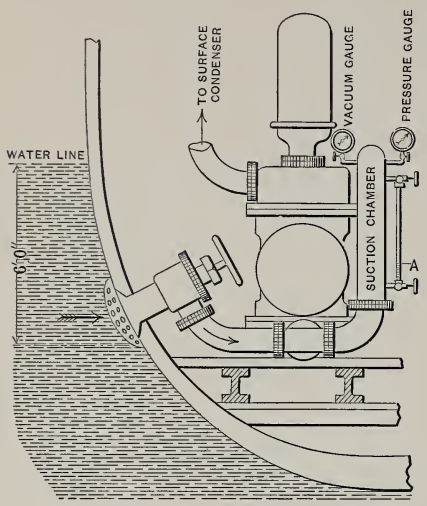


FIG. 8.

square inches. With the gate valve one turn open, it was found by careful measurement that the area of opening was about 0.14 square inch. With the

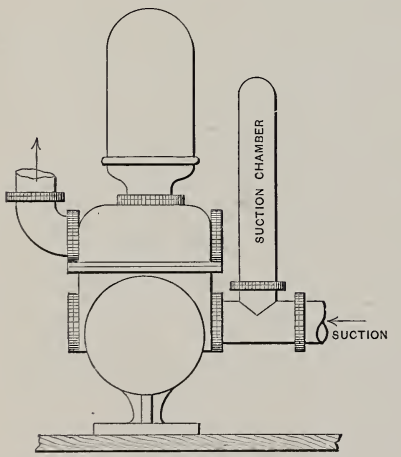


FIG. 9

valve two turns open, the actual opening was 0.78 square inch. Before completing the test, the pump was worked up to the extreme speed of 120 double strokes per minute, and at this still ran quietly.

In marine practice it is sometimes very difficult to properly locate a suction air chamber on account of limited space. When not convenient to arrange suction air chambers on either plan as shown in Fig. 1, and when the suction approaches the pump horizontally, the arrangement shown in Fig. 7, or the arrangement shown in Fig. 8 (which latter shows the circulating pump on the U. S. S. *Dolphin*, referred to later on), are also very efficient for suction air chambers.

Fig. 9 shows an arrangement which, from the following incident, proves that it was of little or no value. This case was in connection with a 1500 I. H. P. compound stationary engine where the circulating pump, which supplied the surface condenser, had nearly 400 feet of 14-inch suction pipe. The writer urged the use of a suction air chamber, and understood that it would be placed as shown in Fig. 10. When visiting the place later on, the writer was not surprised at the complaint about the noise made by the pump. They had not properly located the suction air chamber. They had placed it at right angles to the horizontal suction pipe (as shown in Fig. 9), explaining that for certain reasons they could not approach the pump with the suction pipe on a vertical line, as was originally intended. The trouble was corrected by removing this suction air chamber from the position in which they had placed it and putting it on the opposite side of the pump, with a suitable elbow, as shown in Fig. 11. Thus the impact of the water was received over and across the water barrel of the pump into the suction air chamber. It is hardly necessary to say that after this change had been made the pump worked with perfect freedom from water hammer.

In the case of the writer's experience on the U. S. S. *Dolphin*, the circulating pump was located 6 feet below the water-line. The pump was horizontal, direct-acting, with 26-inch water cylinder and 24-inch stroke, attached to which, by suitable connections, were

two vertical single-acting air pumps. Referring again to Fig. 8, which shows the arrangement of the suction air chamber in this case, it was amusing

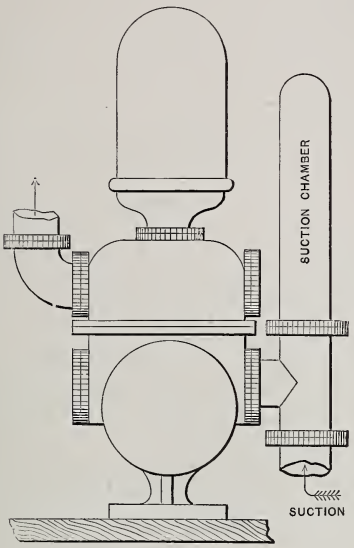


FIG. 10

to hear the remark of one engineer who insisted that it would be of no advantage, that this suction air chamber would at once fill up because of the pressure of water in the suction pipe, and consequently would defeat the very object desired. This and other opinions were expressed on the subject, but there was no one who anticipated correctly the conditions that actually prevailed in the suction chamber when the pump was operated. As shown, there was placed on the side of the suction air chamber a long glass water gauge, about 4 feet high, and at the top of the chamber were also placed a light spring pressure gauge and a vacuum gauge. As remarked, it was thought the suction chamber would fill up with water on account of the pump being so much below water-line. As a matter of fact, when the pump was working at any speed, the water never rose higher than 6 inches from the lower end of the glass water gauge, at which place (see point *A*) it oscillated several inches at each stroke of the pump. Alternately the gauges showed about 5 inches vacuum and two to three pounds pressure. This demonstrated conclusively the decided value of the suction air chamber, because it not only relieved the pump of the impact of the water column against the piston at each reversal of stroke, but it also secured full value of the head of water on the suction. When the pump was first started the sea cock was partially closed, snifting in some air through a small check valve on the suction pipe to prevent water hammer. Against this the writer protested, urging that by so doing they were throwing away so much power by decreasing the pressure of water in the suction pipe. To prove this, the strokes of the pump were increased from ten to fifteen more per minute than when the sea cock was entirely opened, the steam pressure and position of steam throttle being the same in each instance.

If pump makers would take the trouble to always recommend suction

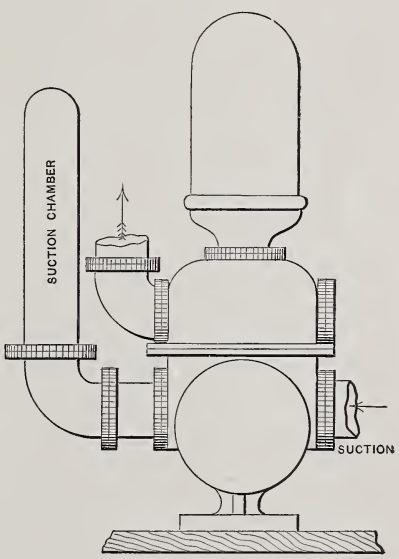


FIG. 11

chambers, and pipe fitters would take a little more care in properly locating them, there would be less complaint about jar and noise in a pump, to say

nothing about saving of wear and tear. This remark applies to pumps of all types, whether single, duplex, vertical or horizontal, especially to pumps that are liable to run at the higher rates of speed, as, for instance, in the case of fire pumps, ash ejector pumps, wrecking pumps, etc. There are thousands of cases of noisy pumps that could be entirely relieved from water hammer by the use of properly located suction air chambers.

Current Topics

With all the criticism that has been heaped on the water-tube boilers used in ships of the British Navy and on those responsible for their installation, it becomes interesting and proper that something should be heard of the other side of the question, and it is, therefore, worth while to read the memorandum on the subject, submitted by the British Admiralty a few months ago to both Houses of Parliament. The document is full of interest, and shows how urgent the necessity is of making engineering knowledge of paramount importance in the personnel of a modern navy. In summing up, the report concludes as follows:—Surprise is naturally felt by those who are not fully conversant with the whole of the circumstances that difficulties connected with the management of water-tube boilers and high-pressure machinery should take so long to overcome, and they are apt to assume that because they are not all removed in the three or four years that have elapsed since water-tube boilers were introduced into the British Navy, they must be insuperable. A little consideration will show that up to the present, and for some time to come, the engine-room staff of every newly-commissioned water-tube boiler ship must be largely composed of those who have had no previous experience with this type of machinery, as the number of water-tube boiler ships in commission has up to the present borne so small a proportion to the total number of ships for which crews are provided. The rate at which crews can be trained will increase rapidly as more water-tube boiler ships become available, and as special arrangements for training engineers, engine-room artificers and stokers augment the number of men with experience of these boilers.

When defects of any importance occur in any part of the machinery of new ships, the best method of dealing with them is considered by the makers of

the machinery, who are responsible for the design and have great interest in maintaining its efficiency; by the dockyard officers, who have the experience of all similar defects that have been dealt with at their own yard, and by the Admiralty engineers, who are in close touch with all the dockyards, as well as with all the contractors and the officers afloat. For each defect, the first thing is to determine the true cause, which is often difficult to ascertain. It must then be determined whether the defect might not be avoided if some different method of treatment was adopted, or some precaution to prevent improper management was introduced, and, finally, if an alteration is to be made, what the alteration should be in each case. Each of these steps requires time for investigation and experiment, which must, as a rule, be carried out without interfering more than can possibly be helped with the service on which the ship is employed. Alterations, when decided on, can be carried out only when the ship can be spared, which is generally only when she is in dockyard hands for other purposes, and the efficiency of each alteration must generally be tested by actual experience in one or two ships before it is carried out generally. Improvement is, however, steady and continuous, and may be expected to become more rapid as all concerned, including the engineering staffs at the Admiralty, dockyards and contractors' works, as well as the engineers of the ships, gain experience.

THERE is no doubt that the advance from cylindrical to water-tube boilers, with its accompanying great increase in pressures from 150 pounds to 250 pounds at the engines, has for the present added greatly to the anxieties of the engineers in charge of the machinery. This is inevitable when any change of this magnitude is made, involving, as it does, such a multitude of small details. It should be fully recognised that these officers have at first a difficult task, and that time is necessary to enable them to gain experience in the best way of dealing with all emergencies that arise under the new conditions. Most of the difficulties are got over after a ship has been some time in commission, especially if the service she is employed on permits of time and opportunity being given to remedy all the defects that are discovered; and the difficulties are all of such a nature that it may be confidently expected that they will be successfully overcome, by comparatively small modifications of design or manipulation, as experience is gained. Men-of-war must be designed to cope with those of foreign countries that they may have to meet in war, and no country can afford to relinquish such a decided advantage in speed for a given weight as trials have shown to be given by water-tube boilers, or the great advantage of getting up steam and increasing speed rapidly, unless there were strong grounds for supposing that the numerous defects in details which now render the machinery somewhat less reliable than older and well-tried types, were likely to be permanent. This is certainly not the case. All the experience in British commissioned ships shows that the defects from which they at first suffered are being rapidly overcome.

MAGNALIUM is the name of a new aluminium alloy which was recently brought out in Austria, and is essentially different from all other important aluminium alloys in this respect, that the latter contain only a small per centage of aluminium, while the new product is composed essentially of aluminium,—from 70 to 98 per cent.,—the remainder being magnesium. As magnesium is lighter than aluminium, the specific gravity of the alloy is lower than that of the pure metal and decreases in indirect ratio to the amount of magnesium present. In its other properties, also, magnalium is different from alloys previously discovered, and from aluminium itself. According to particulars given in *The Iron Age*, the new material is hard, easily worked, possesses great

powers of resistance to atmospheric influences, and has a beautiful appearance. It is also ductile and can be rolled into tubes and wire just as well as aluminium. According to the amount of magnesium present in the alloy the properties of magnalium vary considerably. With 10 to 25 per cent. of mangesium the alloys are easily worked. A 10 per cent. alloy possesses the same mechanical properties as zinc. An alloy of 100 parts of aluminium and 15 parts of magnesium corresponds to good casting brass, while with the same amount of aluminium and 20 parts of magnesium the alloy possesses the properties of hard-drawn brass wire. For making castings a magnalium containing 10 to 15 per cent. of magnesium is especially suited. It melts at about 700 degrees (C.), remains hot for a long time, and fills out even the most delicate details of the mould in a faultless manner. It is true that a rather considerable funnel-shaped cavity forms at the gate, but this may be counteracted by a larger sinkhead. The casting is dense and free from blow-holes, and the surface remains so bright that pickling is not necessary. Magnalium, indeed, possesses a magnificent colour. It is almost silvery white, acquires a vivid lustre by polishing, and may even be rendered reflective. The colour and gloss are not affected by the atmosphere or by water, excepting, possibly, that a dull film forms on the surface; but the resistance to tarnishing increases with the purity of the magnesium and the aluminium.

Magnalium castings may be worked in the same manner as brass. Long spiral shavings may be turned off and even the finest threads be cut. It can be bored and worked with the finest drills, and filing may be done without the files becoming clogged or filled up, as happens in working pure aluminium. Especially the softer alloys,—*i. e.*, those containing less magnesium (10 to 15 parts of magnesium to 100 parts of aluminium),—may, when cold, be forged, drawn into wire and rolled out into tubes and plates. While aluminium castings possess hardly the tensile strength of cast iron, the strength of the alloy containing 10 to 20 per cent. of magnesium is, according to the tests conducted so far, 42,000 to 60,000 pounds per square inch, with an elongation of 10 per cent. The strength of the alloy is, therefore, considerable, and it increases with the proportion of magnesium; at the same time, however, the alloy becomes more brittle. When it is added, further, that magnalium can be soldered, just as well, at least, as the pure aluminium, probably all the advantages of the new alloy have been stated.

Some of Mr. Nikola Tesla's latest work has taken shape in a patent for utilising the insulating effects of freezing, and we are told, to use his own words, that the proposed method of insulating electric conductors "consists in laying or supporting the conductors in a trough or conduit, filling the trough with a material which acquires insulating properties when frozen or solidified, and then causing a cooling agent to circulate through one or more channels extending through the material in the trough so as to freeze or solidify the material." It has been known since Faraday's time that ice is an excellent insulator, and this is the fundamental idea upon which Mr. Tesla has based his several proposed applications. So far as these, however, are designed to provide for effectively insulating thousands of miles of electric light and power conductors,—something which he is reported to have included among the immediate practical possibilities,—it is safe to say that there will be disappointment somewhere. A goodly measure of patience will have to be cultivated in waiting for the attainment of this end.

It is worth bearing in mind that noise, like heat, is a form of energy, and that power can be wasted almost as readily in producing one as the other. Indeed,

the engineering aspect of noise has frequently suggested itself as an ever-timely subject for consideration, and it is interesting, therefore, to find that it has been taken up by *The Engineer*, of London, substantially as follows:—If we had at hand a convenient method of calibrating it, sound might be found a not very indifferent method of measuring power. We are so accustomed to regard sound as the natural accompaniment of mechanical motion that the fact that it is a monitorial voice, ever telling us of energy wasted, generally escapes attention. The noise of running wheels, of moving water, the crackling of a belt, the hum of a dynamo, the rattle of a motor car or a railway train, are as sure indications of energy resolved into a useless form, as the crash of broken crockery and the lamentations of a careless servant. Although the ear as a measuring instrument is of little value, it is far more sensitive as an indicator than is perhaps generally understood. It has been found by experiment that the noise produced by a ball of pith, one milligramme in weight, falling on a hard, smooth surface from a height of one millimetre, can be heard by an ear placed one centimetre away. With this fact before us, it is not surprising that even the best machinery in motion should be accompanied by very audible noises. It has been found that a play of a brass on a crank-pin, so small that the expansion of the pin caused by a small rise in temperature is sufficient to cause seizing, will produce, when run at a high speed, a quite alarming knock. Speed in all considerations of this sort is, of course, a pre-eminent factor. We all use this knowledge intuitively in gauging the speed of a rotating disc or shaft when sight is unable to aid us. We hear above all others a predominant series of small percussions, and from the note produced we estimate the speed. The physicist tells us that an insect's wing moves so many times a second, by comparing the note it makes with the vibrations of a tuning-fork. In the same manner the speed of fast-running machinery can be measured with no little accuracy by allowing it to set a spring in vibration by a succession of regular taps. Savart caused a rotating notched disc to set a piece of paper in vibration, increasing the speed until the note produced harmonised with that produced by a tuning-fork of known beat, when he was able to state the exact number of revolutions per minute of the disc. So much for speed.

But for the measurement of power we require to know the pressure and the distance through which it acts. Now the loudness of a blow is, generally speaking, proportional to its force, and the force to the distance through which it acts. Or, expressing it slightly differently, the intensity of a note is proportional to the force employed to produce it. The intensity multiplied by the speed is then an absolute indication of the power expended. This is a calculation we all make unconsciously and involuntarily. We estimate the speed of a train by the noise it makes as the wheels pass the joints in the rails. Were our ears educated sufficiently, we might tell approximately the power exerted by the engine. We should associate a certain degree of loudness with a certain weight of train and a certain rhythm with a certain speed, and unconsciously arrive at an estimate of the power exerted. In this case noise, as in all other cases, is a direct indication of wasted power. Power so lost on railways has been continuously lessened by the adoption of longer rails, so reducing the number of joints, and by the more careful balancing and general accuracy of construction of rolling stock. At present to the man in the street the most noisy declaration of squandered power is in the motor car. Does one grasp that every puff of exhaust means that gases still full of energy are allowed to expend it valuelessly in disturbing the atmosphere? That every jar and rumble and shake means expenditure of power which the engine has to provide? A mile on the bone-shaker of thirty years ago was harder work than ten on a modern bicycle, and it proclaimed the

fact that it was an inefficient and extravagant machine in a sufficiently noisy manner. Even with typewriters and sewing machines, the less noise they make the less power is absorbed in working them.

GENERALLY speaking, *cæteris paribus*, the less noise machinery makes the more efficient it is likely to be. Even the interposition of some non-resonant material, as, for example, the use of wooden or hide teeth in wheels, whilst reducing sound, if we may so put it in a more or less fictitious manner, adds to the efficiency, because it introduces a resilience which minimises shocks, just as the springs of a coach make it not only more comfortable for the passenger, but easier going for the horses. The question of friction and the noise produced by rubbing surfaces is of very considerable and much more frequently recognised importance, but materially it differs but little either in expression or in effect from the noise of shock. A rod or wire can as readily be caused to produce a note by rubbing it with a resinous glove as by striking it with a hammer. How close the connection is a moment's consideration will show, and will give us the hint that we cure only half the complaint in oiling machinery if we still allow knock, and jump from one evil to another if in order to reduce friction we leave excessive play.

THE amount of coal used by the auxiliary machinery on board ship has always been known to be a goodly proportion of the total consumed, and it has been recognised as well that condensation in long lines of steam pipes to different parts of a vessel accounted for much of the fuel. To how much this may amount may be gathered from particulars given by Sir John Durston, engineer-in-chief of the British Navy, of trials of the British ship *Diadem*, according to which the running of one main feed pump, one blowing engine, one auxiliary circulator, one electric-light engine, and two distillery pumps consumed coal at the rate of 6.1 tons per day when two extreme forward boilers were used, or 3.88 tons when two extreme after boilers were employed. The same machines, with the addition of two evaporators, working compound, consumed 8.8 tons of coal per day when supplied by the forward boilers, and 7.09 tons when supplied by the after boilers. That is, the length of steam pipe between the forward and after boilers accounted for 2.12 tons of coal per day in the first trial, and for 1.71 tons in the second. Again, it has been found that in the Japanese battleship *Shikishima* it takes from three and one-half to five tons of coal to run for eighteen hours a day an engine of 65 indicated horse-power situated 160 feet away from the boiler, the total range of steam pipe connected being 500 feet to 600 feet. This works out to from seven pounds to ten pounds of coal per indicated horse-power, of which more than half must have been used in keeping the pipes warm. Figures of this kind have naturally been among the heavy-weight arguments of the advocates of electrical equipments for naval auxiliary machinery. They are undoubtedly suggestive of some possible and very telling economies.

ACCORDING to information from Barcelona, Spain, given in the *Manufacturer*, a tendency exists in that peninsula to increase the manufacture of machine tools on account of the active industrial movement all over that country. It is claimed that such tools could be manufactured in that country at lower prices than they could be bought for in Great Britain or the United States, but they would be inferior in quality, it is feared, on account of lack of experience in their manufacture. The home manufactures, it is believed, could be stimulated by easy terms of payment. Information is also to the effect that there is a demand in Spain for steam engines and boilers, especially for high speed engines for driving electric plants where water power is not available. In many instances

Continental machinery is being taken to Spain, as the users cannot wait for a reasonable time to secure it from more distant points. That it would be remunerative for tool and machinery manufacturers to co-operate and open agencies in several industrial sections of Spain is the opinion of merchants who are well posted on the industrial developments of that country.

THE latest example of steam turbine enterprise is afforded by a 4000 horse-power, single-phase turbine alternator which will be installed in the big central station of the city of Frankfort, Germany. The machine will run at a speed of 1360 revolutions per minute, and will generate current at 3000 volts. It will be by far the largest turbine alternator ever made, competing closely with the largest reciprocating steam-engines thus far built for direct connection, and will help to demonstrate in a very practical manner that the steam turbine has become a fixture in modern engineering practice.

WILLIAM LEDYARD CATHCART

A BIOGRAPHICAL SKETCH

By Engineer-in-Chief and Rear-Admiral George W. Melville, U. S. Navy

SINCE those early years, when, like a Viking, John Paul Jones scoured the Northern Seas, men, —by birth or descent, —of his race have given Scotland her full share in making the history of the United States Navy. I have a rightful pride in this, for, while I regard, as my highest and most sacred privilege, my birth and citizenship in the country whose flag I have served for more than forty years, still the homing instinct turns me, in memory and affection, to the land of my fathers, "Caledonia, stern and wild,"—to those rugged crags and misty moorlands which have bred, for more than three hundred years, so many strenuous fighters on every field of human endeavour.

Sydney Smith's "land of Calvin and oat-cakes" is, as well, the land of Bruce and Wallace, of Robert Burns and Walter Scott, of Gladstone and Lord Kelvin, of a superb soldiery, whose record, from the wars of Marlborough to the trenches of Magersfontein, has been marked by brilliant daring and by heroic self-sacrifice. At Ramillies the Scots Greys rode through the Cuirassiers, capturing the standard of the *Régiment du Roi*. At Waterloo D'Erlon's column was shattered and scattered, at a crisis of the battle, when the Ninety-second Highlanders, gripping the stirrups of the Scots Greys, charged it, in a whirl of horse and foot. At Balaclava the Argyll and Sutherland Highlanders were formed, but two deep, to meet the assault of Russian cavalry in force. To Sir Colin Campbell's order, "There is no retreat, men! You must die where you stand!" their answer came, "Aye, aye, Sir Colin, and if needs be, we'll do that!" In South Africa, when Wauchope fell, the Black Watch followed him, unflinchingly, into the zone of fire; and, in that bloody blunder, life sobbed itself away from many a stern-browed Highlander, who had gone, grimly and knowingly, to death.

Next to the story of our own glorious land, I cherish such memories as these; and I need scarcely say that I turn, with regard, to those of my friends whose right it is to hold them with me. It is with pleasure, therefore, that, at the request of the editor of CASSIER'S MAGAZINE, I write of one of these men, in years past my able assistant and now of Columbia University, New York,—Pro-

fessor William Ledyard Cathcart. He comes of a family which left Renfrewshire, Scotland, late in the seventeenth century, and settled in one of the storm-centres of those days, the "Plantation of Ulster," established, in the north of Ireland, by James I., and, later, cleared of its aboriginal inhabitants by Cromwell. The roll of the defenders in the famous siege of Londonderry, then, in 1689, the chief settlement of Ulster, bears the names of Captains Hugh, James, and Alan Cathcart, who founded the Scotch-Irish branches of their family.

This unsuccessful siege of 105 days was undertaken by the Irish Jacobites in the effort to exterminate the Saxon colony. It is memorable in history for the city's unyielding resistance throughout famine, disease, and almost unexampled suffering. Of the defenders, Macaulay says:—"The whole world could not have furnished seven thousand men better qualified to meet a terrible emergency with clear judgment, dauntless valour, and stubborn patience."

The historian's words were, perhaps, influenced,—as they have been, seemingly, borne out,—by the achievements of the descendants of those early colonists. Aliens, as they have been, in an unfriendly land, they have yet made Scottish Ireland, around Belfast especially, one of the wealthiest and most prosperous sections of the British Empire, through agriculture, manufactures, and shipbuilding. "How that strain endures!" said my friend, David Munro, of the *North American Review*, in commenting on the Scots and Englishry who settled Ulster, whose descendants are found so largely in Pennsylvania, Virginia, South Carolina, and East Tennessee, and who have given the United States four, at least, of its presidents, among them Andrew Jackson and William McKinley.

Professor Cathcart was born in Connecticut in 1855. He is the son of my honoured friend, William Cathcart, D. D., one of a number of able clergymen and physicians who have filled the ranks of his family for generations past. Of the latter, there were, about the beginning of this century, four serving as medical officers in the British Army. The career of one of these, Dr. Martin Cathcart, long of the Seventh Dragoon Guards and a grand-uncle of Professor Cathcart, is worthy of more than passing note, in that to his exertions and representations was due the decision to retain British troops in the unhealthy climate of Burmah for the second campaign against Ava, which resulted in the subjugation of that empire. One of the far-reaching achievements of Dr. Cathcart's long career was his origination and establishment of the Hill Hospitals in the mountains of the various presidencies of India. The sick of the army had previously been shipped to England by the tedious and often fatal route of the Cape, and the success of the new system was such that Lord Combermere, then commander-in-chief in India, on repeated occasions, commended officially its author.

Professor Cathcart received his early training in the public schools of Philadelphia and in the Latin School of Henry Gregory, for many years vice-president of Girard College. He passed a year or more at the University of Pennsylvania, and, in 1873, entered, as a cadet engineer, the United States Naval Academy at Annapolis. I would like, just here, to record my appreciation of the noble work, for the Engineer Corps and the Navy, done by that early engineering course at Annapolis, with whose success the names of several engineer officers will ever be inseparably connected. It was, in later years and to my keen regret, abolished, but not until it had sent forth a body of young men,—all too few, as we find now,—who have supplemented fitly, and, in large measure, succeeded to, the work of their gallant predecessors of the Civil War. Many of these graduates have left us for the pursuits of civil life. Without effort, I recall four who are serving as professors of engineering in leading universities, and two others who are vice-presidents of large engineering companies. As to those who remain in the service, I may say that their worth has

often made me wish that I could multiply them.

Cathcart was graduated in 1875 from the Naval Academy among the honourmen of a class whose record has been exceptionally fine. From that year to his resignation from the Navy, in 1891, to enter private business, his service was that usual with naval officers in peace times,—long cruises on distant seas, with snatches of shore duty intervening, spent, in his case I note, largely in the inspection of machinery building for new vessels. This kind of peace-service only the naval officer will understand fully. It is work which, at sea, combines,—often, and as a matter of course, —danger with duty; which, as a rule, exacts a full measure of time and strength, but which leaves little trace on official records and has, for its reward, only the sense of labour fitly done.

If Cathcart were telling his own story, I do not doubt that, like all those who have followed the sea, he could fill it with incident. As for me, all that I can say is that the official records show his service to have been fully successful and such as to win, as an engineer, an officer, and a gentleman, the high commendation of superiors. In my official letter, as Engineer-in-Chief, to him, under date of January, 1891, at the time of his resignation from the Navy, I find myself saying:—" I feel that the Engineer Corps and the service have lost a most valuable officer, whose place it will be hard to fill." These views I hold, perhaps more strongly, still.

The work which first made Cathcart one of my assistants I am not likely to forget. The hour was a vital one to naval engineering, since Secretary Whitney, —continuing the development of the New Navy begun by his predecessor, Mr. Chandler,—was impressed with the fact that the nation needed warships second to none, and that if American designs were to be followed they must be fully equal to those that could be prepared abroad. To make the situation more complicated, the office of the engineer-in-chief was vacant, and active efforts were on foot to keep it permanently so.

Having at that time but lately returned from the Arctic, in settling the affairs of the *Jeannette* Expedition, I had several conferences with the Secretary. It was, perhaps, the result of these interviews that Mr. Whitney concluded that I might be the man for the emergency; and, on my affirming, in answer to his query, that I could, with proper assistance, prepare machinery designs equal to those of noted British builders, he issued the necessary orders for me to go ahead with the plans.

With the aid of a small, but brilliant, band of assistants, the machinery of the *San Francisco*, a thoroughly satisfactory and successful ship, was designed, and, shortly after the completion of her plans, I was appointed Engineer-in-Chief. The preparation of these preliminary plans for the *San Francisco* was practically the beginning of my engineering labour for the New Navy, and of that hastened, but accurate, work Cathcart did his full share. When the far-reaching results are considered which have followed the success of these designs, it will not seem strange that I bear in kindly memory the men who, in the summer heat, toiled with me at my task.

Since his resignation from the service, Cathcart has been very loyal to his former corps, and this, too, when, at times, such loyalty meant not a little personal sacrifice. The passage of the Naval Personnel Bill has, happily, removed many of the disabilities under which engineer officers in the United States Navy for years have laboured. One great factor in the long agitation which led to this result was the awakening of public interest in naval matters generally, and in naval engineering especially. A provision,—as a rule, most wise,—of the naval regulations, forbids officers from such communications to the press as are intended to influence legislation. Under this restriction, the voice of the Engineer Corps was silenced, and, for needed reforms, it was dependent upon its friends in Congress and upon such writers, outside of the service, as championed its cause.

It was in this that Cathcart served well his old corps. Unsolicited and

often without the knowledge of its officers, his complete understanding of, and eager interest in, the subject, bore fruit in a number of signed articles or editorials which aided materially in moulding public opinion. I recall an instance of this which may be worth the telling. One of the articles was a comprehensive, legal review of the subject which appeared in the pages of this magazine. While its conclusions were severe, the case seemed most logical and clear-cut. It had not been long in print before I received a letter from a distinguished foreign officer, who said that the article had won him to a complete reversal of his views upon important points of the question. This was one of a number of similar instances which proved the value of this work.

At the outbreak of the late war with Spain, Cathcart volunteered for service, and, at my instance, was ordered to duty, as my assistant, at the Bureau of Steam Engineering, where he was, during hostilities, in charge of confidential work. In this connection, I may say that I have learned to value certain of his characteristics, when engaged in engineering or other investigation. Blessed with a somewhat troublesome, perhaps racial, spirit of incredulity, he will take nothing at second hand, if, by any labour, original sources of information can be reached; and, further, the subject will be viewed impartially from all points. His work is, in marked degree, thorough, finished, and trustworthy.

Within late years Cathcart's energies have been turned to what I believe to be his natural and hereditary field,—that of instruction and investigation. He was, for a time, the head of the Department of Marine Engineering at the naval school founded, at Fordham Heights, New York City, by the late William H. Webb, who was, in his day, in the foremost rank of American shipbuilders. This institution, which is doing most worthy work in engineering and naval architectural education, is now under the presidency of a distinguished marine engineer, whom I am proud to call my friend,—Stevenson Taylor, Esq. From his duties at Fordham, Cathcart was called to the adjunct professorship of mechanical engineering at Columbia University, New York. This university has recently established, under his leadership, courses in marine engineering and naval architecture. For such courses New York, with its splendid harbour and enormous shipping, gives an unrivalled field, and results of moment to our merchant marine may be expected to follow their establishment.

As a closing word, it may be well to say that Cathcart is a man of heart as well as mind, and that his kindly nature and admirable qualities of character have won for him the lasting friendship of many men of worth with whom he has come in contact. Of sensitive, yet steady and strong, spirit, he stands for that high form of culture which, shaped and given a precision and solidity by exacting intellectual endeavour, is peculiarly the outcome of a life's labour and association in the engineering profession.

It has given me pleasure to write this brief review of some salient points in Professor Cathcart's career. Added to my personal interest in the subject, there is the feeling that he is, in some measure, but a type of the host of able officers who have, as my assistants, served the nation so faithfully and so well in the rebuilding of our fleet. I ever welcome the opportunity to record my appreciation of their work.

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